THE STRINGING, SCALING AND PITCH OF PIANOS BUILT IN THE VIENNESE AND SOUTH GERMAN TRADITIONS 1780 - 1820

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"Alle Wissenschaften und Künste, sagt Herr von Fontenelle, haben ihr Hirngespinst, wornach sie lauffen, ohne es jemahls zu erreichen. Man erwischet aber unterwegens allezeit sehr gründliche Erkenntnisse. Die Chymie hat den Stein der Weisen, die Meßkunst die Quadratur des Zirckels, die Astronomie die Seelänge, die Mechanick die immerwährende Bewegung. Es ist unmöglich, alles dieses zu finden, aber sehr nützlich, darnach zu suchen."

A quotation given in Friedrich Wilhelm Marpurg, *Der critischen Musicus an der Spree*, Berlin 1750, 200.

For Klaus and Andreas

TABLE OF CONTENTS

CHAPTER II

CHAPTER III

Acknowledgements

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Abstract of thesis

Between 1780 and 1820 the changes in the pianos built in the Viennese and South German traditions were rapid and extensive. These changes manifest themselves in the stringing, the scaling and, to a lesser degree, the pitch of the pianos of the firms of Johann Andreas Stein (1728-1792), his daughter Nannette Streicher (1769-1833), Anton Walter (1752-1826), Ferdinand Hofmann (1756-1829) and their pupils and followers. General trends can be observed. The compass was enlarged and the extent of both the triple stringing and the back-pinning was increased. Strings were made continually thicker, presumably to meet the demand for more volume. Because thicker strings are relatively weak compared to thinner ones the strings were shortened to avoid breakage. The case construction was strengthened to withstand the greater tension. Improvements were made in the tensile strength of music wire from about 1820 onwards allowing makers to lengthen the strings again.

The gauge numbers, which indicate the makers' intentions for string thicknesses and which are found stamped or written on the instruments, probably do not refer to different gauge systems but to one single system. The gauge numbers refer to nominal diameters which, with considerable variation from one wire drawer to another, were gradually increased in actual diameter over time. This single gauge system sometimes contained half gauges, sometimes not.

Many builders did not use the Pythagorean principle in which the lengths of the strings for two notes an octave apart are related in the ratio 1 : 2. Instead, many makers used the ratio 1 : 1.95, achieved in practice by giving the upper note of a pair of notes two octaves apart the Pythagorean length of the note a semitone lower than the upper note. The use of the tapered scaling may be related to the phenomenon known today as tensile pick-up in which thinner strings are relatively stronger than thicker strings.

In the extreme treble the strings are usually even longer than a tapered scaling requires, probably because the makers wanted to keep the bridge on free soundboard rather than because of scaling considerations. Practical considerations took precedence over theory. Usually, for example, no compensation was made for the hiatus in the scaling caused by the interpolation of a gap spacer. Again, the practical need to align the strings above the hammers was of greater importance than the accuracy of the scaling.

On the basis of breaking tensions for samples of wire from about 1800 and 1820, established by practical experimentation, it appears that in about 1785 the strings were probably stressed to a reasonable maximum, about two semitones from breaking point. By about 1820 strings were maintained further from breaking point, perhaps because of heavier playing techniques.

In pianos, the scaling cannot be taken as an indication of pitch because the length of a string is also dependant on its thickness. Nevertheless, instruments intended for destinations where an especially high pitch was used may have been designed with especially short scalings while instruments for low pitch destinations were scaled normally and the strings tuned down. The differences in these pitches are probably not related to the traditional double pitch standard in which there is a choir pitch and a chamber pitch a tone apart.

There is considerable variation in the design of the pianos in general and in the solutions to the different problems involved in their stringing, scaling and pitch in particular. This variation is found to exist both synchronically amongst the different makers and diachronically within the work of each individual maker. While general trends do emerge, individual pianos cannot be dated on the basis of single aspects of their design. The period 1780 to 1820 is not only characterised by rapid change but also by rich diversity.

Declaration

The research and work embodied in this thesis, and its composition, are my own.

Michael Latcham

List of illustrations

List of tables

List of graphs

List of instruments mentioned in the text by abbreviation together with their codes and brief commentaries.

Johann Andreas Stein (1728-1792)

S/1777	Accademia filarmonica, Verona, on loan from the Museo di Castelvecchio, Verona
S/1781	Historiska Museet, Gothenburg, Inv. No. GM4478
S/1782	Privately owned in Italy
S/1783a	Privately owned in Germany
S/1783b	Ringve Museum, Trondheim, Inv. No. RMT771
S/1783c	Conservatorio di Musica San Pietro a Majella, Naples
S/1783d	Museum of Fine Arts, Boston, U.S.A., Inv. No. 1977.63
S/1783e	Musikinstrumenten-Museum, University of Leipzig, Inv. No. 171
S/1784	Privately owned in the U.S.A. (formerly Museum of Art, Toledo, U.S.A., Inv. No. 25.1047)
S/1785	Mozart-Haus, Augsburg, Germany
S/1786	Musée Instrumental de Bruxelles, Brussels, Inv. No. M.I.1634
S/1788a	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1097
S/1788b	Württembergisches Landesmuseum, Stuttgart, Inv. No. G 4185
S/c.1790	Collection Neumayer , Bad Krozingen, Cat. No. 22
S/1790	Stadtmuseum, Munich, Inv. No. 88-13
S/1792	Historisches Museum, Basel, Inv. No. 1986.112
S/1793	Kunsthistorisches Museum, Vienna, Inv. No. SAM 626

This is a complete list of the known instruments (excluding two clavichords and one organ) by Stein.

Geschwister Stein
(the firm operated under this name from 1792-1802)

S/c.1796/27	Metropolitan Museum of Art, New York, Inv. No. 64.252
S/1800	Historisches Museum, Basel, Inv. No. 86.1913

The existence of one other piano by the *Geschwister Stein* is known to the author. In addition, another piano in the Germanisches Nationalmuseum Nuremberg (Inv. No. MIR 1104) is attributed to the *Geschwister Stein* by the author.

Nannette Streicher (1769-1833)

S/c.1804a	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1107
S/c.1804b	Musikinstrumenten-Museum, University of Leipzig, Inv. No. 3189
S/1805/649	Privately owned in Germany
S/1805/673	Sibelius Museum, Turku, Finland, Inv. No. 120*
S/1807/733	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 135
S/1808/764	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1117
S/1811/902	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 119
S/1813/961	Kunsthistorisches Museum, Vienna, Inv. No. SAM 844
S/1814/1031	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 118
S/1814/1060	Württembergisches Landesmuseum, Stuttgart, Inv. No. W 26, 2
S/1816/1117	Collection Neumayer, Bad Krozingen, Inv. No. 28
S/1816/1147	Historisches Museum, Basel, Inv. No. 1986.105
S/1819/1415	Historisches Museum, Bern, Inv. No. 33174
S/1819/1425	Technisches Museum, Vienna, Inv. No. 15 276
S/1820/1486	Händel-Haus, Halle, Inv. No. MS 39
S/1820/1550	Privately owned in Germany*
S/1820/1563	Goethe-Haus, Weimar*
S/1823/1756	Cobbe Collection, England, on loan from H.M. Queen Elizabeth II

A total of twenty-seven instruments inscribed *Nannette Streicher* is known to the author. Another four are known to have existed but are now lost. The author is grateful to Marketa Kivimarki for details of S/1805/673, to Bernard von Tucher for details of S/1820/1550 and to Marieke Teutscher for details of S/1820/1563. The author is also grateful to Hugh Roberts of The Royal Collection for permission to publish details of S/1823/1756.

Nannette Streicher *und Sohn*
(the firm operated under this name from 1823-1833)

S/1826/2053	Privately owned in Germany
S/1827/2185	Musikinstrumenten-Museum, University of Leipzig, Inv. No. 3276
S/1828/2237	Händel-Haus, Halle, Inv. No. MS 41
S/c.1828	Technisches Museum, Vienna, Inv. No. 15 272
S/1830/2383	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 117
S/1832/2584	Privately owned in Germany

The existence of a total of twelve instruments inscribed *Nannette Streicher und Sohn* is known to the author.

Johann Baptiste Streicher (1796-1871)

S/1835/2750	Privately owned in Austria
S/1837/2991	Sammlung historischer Musikinstrumente des Musikwissenschaftlichen Instituts der Universität Erlangen-Nürnberg, Erlangen, Inv. No. R16*
S/1839/3261	Privately owned in The Netherlands
S/1839/3299	Sammlung historischer Musikinstrumente des Musikwissenschaftlichen Instituts der Universität Erlangen-Nürnberg, Erlangen, Inv. No. N8*
S/1839/3304	Technisches Museum, Vienna, Inv. No. 13 731
S/1839/3338	Privately owned in England
S/1846/3985	Privately owned in the U.S.A.
S/1847/4032	Privately owned in The Netherlands
S/1855/5015	Kunitachi College, Japan Regd. No. 256*

The existence of a total of fifty instruments inscribed *J. B. Streicher* is known to the author. The author is grateful to Johan Wennink for additional details of S/1835/2750. Details of S/1837/2991 and S/1839/3299 were taken from *Quellenkataloge zur Musikgeschichte Nr.25*, ed. Richard Schaal, *Sammlung historischer Musikinstrumente des Musikwissenschaftlichen Instituts der Universität Erlangen-Nürnberg* by Thomas Jürgen Eschler, Wilhelmshaven 1993.

Johann Baptiste Streicher *und Sohn*
(the firm operated under this name from 1857 to 1896 when production stopped, one hundred years after Nannette moved to Vienna)

S/1858/5459	Ringve Museum, Trondheim, Inv. No. RMT 75/7
S/1861/5843	Sweelink Museum, Amsterdam
S/1864/6298	Collection Neumayer, Bad Krozingen, Cat. No. 33
S/1867/6511	Finchcocks, England
S/1868/6688	Privately owned in the U.S.A.
S/1871/7119	Privately owned in the U.S.A.
S/1871/7199	Privately owned in the U.S.A.
S/1873/7383	Haags Gemeentemuseum, The Hague, Inv. No. 8-1991

The existence of a total of sixty-six instruments inscribed *J. B. Streicher und Sohn* is known to the author.

Anton Walter (1752-1826)

W/c.1782a	Haydn-Haus, Eisenstadt, Austria
W/c.1782b (attr.)	Mozart-Geburtshaus, Salzburg,
W/c.1782c (school)	Haydn-Geburtshaus, Rohrau, Austria
W/c.1782d (school)	Technisches Museum, Vienna
W/c.1782e	Mozart-Geburtshaus, Salzburg
W/c.1785a	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1098
W/c.1785b	Privately owned in Germany (Sotheby, London, Cat. No. 162, 1993)
W/c.1785c	Privately owned in Italy
W/c.1790	Privately owned in Germany
W/c.1795	Oberösterreichisches Landesmuseum, Linz, Inv. No. Mu 89
W/1796	Privately owned in Italy
W/c.1800a	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 109
W/c.1800b	Kunsthistorisches Museum, Vienna, Inv. No. SAM 454
W/c.1800c	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1099
W/c.1800d	Kunsthistorisches Museum, Vienna, Inv. No. SAM 539,
W/c.1800e	Privately owned in Austria
W/c.1800f	Rector's Palace, Dubrovnik*
W/c.1800g	Privately owned in Switzerland*

This is a complete list of the grand pianos made by or ascribed to Walter from before Schöffstoß joined the workshop in about 1800.

Anton Walter *und Sohn*

W/c.1805a	Germanisches National Museum, Nuremberg, Inv. No. MIR 1108
W/c.1805b	Staatiches Institut für Musikforschung, Preußischer Kulturbesitz, Berlin Musikinstrumenten-Museum, Inv. No. 5423
W/c.1815a	Sotheby, 1991
W/c.1815b	Privately owned in the U.S.A.
W/c.1815c	Württembergisches Landesmuseum, Stuttgart, Inv. No. G8, 59
W/c.1815d	Sotheby, 1993
W/c.1815e	Technisches Museum, Vienna
W/c.1815f	Privately owned in Germany
W/c.1815g	Yale University Collection of Musical Instruments, New Haven, U.S.A. Cat. No. 22*
W/c.1817	Privately owned in Italy
W/c.1820	Privately owned in Italy

Other pianos signed *Walter und Sohn*: Národní Museum, Prague, Inv. No. 1924E; Minon, Japan; privately owned in Italy, U.S.A., Austria. There is one I ascribe to Walter but bearing the name Beringer in the Munich Stadtmuseum.

Ferdinand Hofmann (1756-1829)

H/c.1784a	Privately owned in Germany
H/c.1784b	Kunsthistorisches Museum, Vienna, Inv. No. SAM 437
H/c.1785a	Privately owned in Austria
H/c.1785b	Musikinstrumenten-Museum, University of Leipzig, Inv. No. 176
H/c.1785c	Metropolitan Museum of Art, New York, Acc. No. 1984.34
H/c.1785d	Pokrajinski Muzej, Ptui, Slovenia, Inv. No. GL66 S, Cat. No. 50
H/c.1790a	Technisches Museum, Vienna, Inv. No. 351
H/c.1790b	Privately owned in The Netherlands
H/c.1795a	Privately owned in Italy
H/c.1795b	Landesmuseum Johanneum, Graz, Inv. No. KGW 21.328
H/c.1795c	Shrine to Music Museum, South Dakota, U.S.A, Cat. No. 5657
H/c.1795d	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 107
H/c.1795e	Privately owned in Japan
H/c.1795f	Privately owned in Austria
H/c.1795g	Privately owned in Japan
H/c.1795h	Kunsthistorisches Museum, Vienna, Inv. No. SAM 538
H/c.1800	Privately owned in England
H/c.1805	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1109
H/c.1815	Formerly in the Metropolitan Museum, New York, Acc. No. 1984.396, now privately owned in the U.S.A.
H/c.1820	Bundes Mobilien Depot, Vienna, Acc. No. L2914.

This is a complete list of the grand pianos by Hofmann. There are also three square pianos and one clavichord by him.

Johann Jakob Könnicke (1756-1811)

K/1	Collezione Nationale, Rome, Inv. No. 0680, c.1795
K/2	Yale University Collection of Musical Instruments, New Haven, U.S.A. Cat. No. 21, c.1795
K/3	Haydn-Haus, Vienna, Inv. No. 688, 1796
K/4	Germanisches National Museum, Nuremberg, Inv. No. MINe108, 1796
K/5	Kunsthistorisches Museum, Vienna, Inv. No. SAM 610, c.1800
K/6	Kunsthistorisches Museum, Vienna, Inv. No. SAM 556, c. 1810
K/7	Germanisches National Museum, Nuremberg, Inv. No. MIR 1112, c. 1810

K/5 is a so-called *Harmonie Hammerflügel* with six diatonic keyboards giving 31 notes per octave and a *Stoßmechanik*. The existence of two other instruments by Könnicke is known to the author. One is in the Poznan museum, Poland, Inv. No. MNP 1.65. The other was sold at auction and brought to my notice by Alfons Huber. A third, vertical grand in the Metropolitan Museum of Art, New York, Acc. No. 1980.218, is, in the author's opinion, probably not by Könnicke.

Johann Schantz (c.1762-1828)

Sz/1	(square) Kunsthistorisches Museum, Vienna, Inv. No. GdM 6, c.1790
Sz/2	Privately owned in The Netherlands, c.1790
Sz/3	Kunsthistorisches Museum, Vienna, Inv. No. SAM 386, c.1795
Sz/4	Privately owned in England, c.1795
Sz/4a	Collection Scala, Imola, Italy
Sz/5	Holburne of Menstrie Museum, Bath, England, c.1795*
Sz/6	Accademia Bartolomeo Cristofori, Florence, Italy, c.1795
Sz/7	Gemeentemuseum, The Hague, Inv. No. 1993-0001, c.1805
Sz/8	(square) Yale University Collection of Musical Instruments, New Haven, U.S.A., Acq. No. 16, c.1805
Sz/9	Collection Giulini, Briosco, Italy, c.1810
Sz/9a	Privately owned in Italy, c.1815
Sz/10	Privately owned in Germany, c.1815
Sz/10a	Privately owned in Italy, c.1815
Sz/11	Privately owned in Austria, c.1815
Sz/12	Privately owned in The Netherlands, 1821

Johann Schantz (continued)

Sz/12a	Privately owned in Italy, c.1820
Sz/13	Collection Giulini, Briosco, Italy, c.1820
Sz/14	Privately owned in the U.S.A., c.1820
Sz/14a	Privately owned in Italy, c.1820
Sz/15	Collection Scala, Imola, Italy, c.1820
Sz/16	Nagycenk Museum, Nagycenk, Hungary, c.1820
Sz/16a	Collection Scala, Imola, Italy, c.1825
Sz/17	Privately owned in Italy, c.1825*
Sz/18	Privately owned in Germany, c.1825
Sz/19	Collection Scala, Imola, Italy, c.1825
Sz/20	Collection Scala, Imola, Italy, c.1825
Sz/21	National Museum, Budapest, Hungary, c.1825
Sz/22	Privately owned in Italy, c.1825*

This is not a comprehensive list of the known pianos by Schantz. More exist in Italy, the U.S.A. and Japan.

Ignatz Kober (1755-1813)

{Vienna 1}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 364, c. 1783
{Braunau}	Historical Musem, Braunau, c.1783
{Prague}	Schloß Bertramka, National Museum, Prague, c. 1784*
{Vienna 2}	(square) Kunsthistorisches Museum, Vienna, Inv. No. SAM 496, 1788

{Braunau} is attributed by the author to Kober on the basis of similarities with the other three. The dates of {Vienna 1}, {Braunau} and {Prague} are based on the fact that they are not signed. This Kober would only have been allowed to do after 1785 when he became *Bürger*. Kober died in 1813. Details of {Prague} were kindly supplied by Alfons Huber.

Joseph Wachtl & Jakob Bleyer (fl. 1803-1815)

{Budapest}	Upright 'Apollo', Iparmüvészeti Museum, Budapest, Cat. No. 178, c.1815

Conrad Graf (1782-1851)

{c.1824/423}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 396
{c.1826/609}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 629

Details of both these pianos were kindly provided by Alfons Huber.

Karl Benedickt (dates unknown)

{U.S.A.}	Privately owned in the U.S.A., c.1795
{Ptui}	Pokrajinski Muzej, Ptui, Slovenia, Inv. No. GL3 S, Cat. No. 49, c.1795
{Austria}	Privately owned in Austria, c.1795

Joseph Brodmann (c.1770-1848)

{Austria}	Privately owned in Austria, c.1795
{Halle}	Händel-Haus, Halle, Inv. No. MS-492, c.1800
{Italy}	Privately owned in Italy, c.1805
{Vienna}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 646, c.1810
{Paris}	Musée de la Musique, Paris, Inv. No. 982. 6.1, 1814*
{Netherlands 1}	Privately owned in The Netherlands, c.1815*
{Wörlitz}	Museum Schloß Wörlitz, Germany, 1818, Inv. No. III - 137
{Switzerland}	Privately owned in Switzerland, c.1825*
{Netherlands 2}	Privately owned in The Netherlands, c.1825*

Other grand (and square) pianos known to the author not listed here include two in the Staatiches Institut für Musikforschung, Preußischer Kulturbesitz, Berlin Musikinstrumenten-Museum inv. nos. 4073 and 312. The latter, similar to {Wörlitz}, is probably the one known to have been bought by Carl Maria von Weber in 1813. Other grand pianos by Brodmann are in various private collections. Details of {Paris} and {Switzerland} were kindly provided by Christopher Clarke while details of {Netherlands 1} and {Netherlands 2} were kindly provided by Paul Poletti and Gerard Tuinmann.

Followers of Walter

Johann Georg Gröber (dates unknown)

{Austria 1}	Privately owned in Austria, c.1805*
{Austria 2}	Privately owned in Austria, c.1805*
{New Haven}	Yale University Collection of Musical Instruments, Acq. No. 23, c. 1810
{Austria 3}	Privately owned in Austria, c.1810*
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1114, c. 1810
{Austria 4}	Privately owned in Austria, c.1810*
{England}	Privately owned in England, c.1810
{Austria 5}	Privately owned in Austria, c.1820*
{Innsbruck}	Tiroler Landesmuseum Ferdinandeum, Innsbruck, c. 1830*

The existence of one other piano by Gröber is known to the author. Details of those in Austria were kindly supplied by Alfons Huber.

Michael Rosenberger (1766-1832)

{Germany 1}	Privately owned in Germany, c.1800*
{Vienna 2}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 436, c.1805
{Germany 2}	Privately owned in Germany, c.1805*
{Goudhurst}	Finchcocks Collection, Goudhurst, England, Cat. No. 63, c.1805
{Milan}	Comune di Milano, Museo degli Strumenti Musicali, Cat. No. 621, c.1805
{Italy}	Privately owned in Italy, c.1805
{Vienna 1}	Hochschule für Musik und Darstellende Kunst, Vienna, c.1805*
{Bad Krozingen}	Collection Neumayer, Bad Krozingen, Cat. No. 26, c.1810
{Budapest}	Zenetörténeti Múzeum, Budapest, Cat. No. 177, c.1810
{U.S.A.}	Privately owned in the U.S.A., c.1815
{Austria}	Privately owned in Austria, c.1825*
{Japan}	Privately owned in Japan, c.1825
{Cremona}	Cremona Civic Museum, c.1825*

More pianos by Rosenberger exist. Details of {Germany 1} were kindly provided by Suzanne Wittmayer, of {Germany 2} by Bernard von Tucher, of {Vienna 1} by Robert Brown and of {Cremona} by Christopher Clarke.

Caspar Catholnik (c.1760-1829)

{Halle}	Händel-Haus, Halle, Germany, Inv. No. MS-33, c.1815
{England}	Privately owned in England, c.1815
{U.S.A.}	Privately owned in the U.S.A., c.1815

A considerable number of square pianos by Katholnik (other spellings are used such as Katholnik, Katholnig) are to be found in private and public collections around the world but these three are the only grand pianos by Catholnik known to the author.

Jakob Pfister (1770-1838)

{Munich}	Stadtmuseum, Munich, Inv. No. MI 43-421, c.1800
{Würzburg}	Mainfränkisches Museum, Würzburg, c.1805
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 112, c. 1805

These are the only known grand pianos by Pfister. Unlike the other followers of Walter, it is certain that Pfister was with Walter as a journeyman. He was also with Rosenberger and Brodmann. According to Michael Günther, who kindly drew my attention to {Würzburg} there are also three square pianos by Pfister. Günther's research shows that Pfister worked as journeyman for six years (c.1794-1800) and obtained citzenship of Würzburg together with the right to build pianos there in 1800.

Johann Fritz (?-c.1835)

F/1	Kunsthistorisches Museum, Vienna, Inv. No. SAM 398, c.1810
F/2	Privately owned in England, c.1810
F/3	Privately owned in France, 1813
F/3a	Finchcocks, Goudhurst, England, Cat. No. 48, c.1815
F/4	Händel-Haus, Halle, Inv. No. MS-493, c.1815
F/5	Privately owned in Italy, c.1815
F/6	Privately owned in France, c.1820*
F/7	Privately owned in The Netherlands, c.1820
F/8	Privately owned in Austria, c.1825

There are other grand pianos by Fritz in private ownership in The Netherlands, Italy and the U.S.A. Details of F/3 and F/6 were kindly provided by Paul Poletti.

Followers of Walter (continued)

Ludwig Gress (dates unknown)

{Vienna}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 549, c.1805

Johann Grünenthal (dates unknown)

{Vienna}	Kunsthistorisches Museum, Vienna, Inv. No. SAM 569, c.1800

Ignace Joseph Senft (dates unknown)

{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1105, c.1795

This is the only grand piano by I.J. Senft known to the author.

Mathäus Schautz (1755-1831)

{Solothurn}*	Schlossmuseum Blumenstein, Solothurn, 1792, Inv. No.1903.142
{Germany}*	Privately owned in Germany, c. 1800
{Augsburg}	Städtische Kunstsammlungen, Schaezler Palais, Augsburg, 1802, Inv. No. 9182

I am grateful to Gertrud Kottermaier for bringing {Augsburg} to my attention. Details of {Solothurn} and {Germany} are taken from Georg F. Senn 'Der Klavierbauer Mathias Schautz (1755-1831)', *Glarena*, 46/I, 1997, 3-21.

Franz Joseph Wirth (1760-1819)

{England}	Privately owned in England, c.1790
{Munich}	In the Stadtmuseum, Munich, 1803

Another grand piano, part of a claviorganum, by Wirth is in the Bayerisches Nationalmuseum in Munich, Inv. No. BNM Mu 71. This instrument was kindly brought to my attention by Sabine Klaus.

Karl Lemme (1747-1808)

{New York}	Metropolitan Museum of Art, New York, Acc. No. 26.183,1797

Johann Lodewijk Dulcken (1761-1836)

{The Hague}	Haags Gemeentemuseum, The Hague, Netherlands, Inv. No. 1939-0013, 1794
{Sotheby} (attr.)	Offered for sale at Sotheby's in November 1993, c.1795
{Washington}	National Museum of American History, Smithsonian Institution, Washington, U.S.A., Inv. No. 303.537, c.1795.
{Berlin} (attr.)	Staatiches Institut für Musikforschung, Preußischer Kulturbesitz, Berlin Musikinstrumenten-Museum Inv. No. 5013, c.1795
{Germany} (attr.)	Privately owned in Germany, c.1795

Excluding the piano of The Hague, all of these pianos have been ascribed to Stein in the past. All of them, however, have features unlike those in Stein's pianos, especially the internal construction and the soundboard ribbing which are typical only of the work of Dulcken. There are many other pianos by Dulcken. A list of all the pianos made by him or ascribed to him as communicated to the author by Silke Berdux (August 1996) comprise thirty-two instruments ranging in date from 1792 to c.1825.

There is no direct evidence to prove that Dulcken worked in Stein's workshop but the similarities between the pianos of the two makers show that Dulcken was certainly influenced by Stein. The dimensions of the action parts, for instance the lengths of the key levers from the front to the balance point and from the balance point to the *Kapsel*, are the same in the pianos of the two makers. The inner construction of Dulcken's early pianos, with a bentside liner mounted on blocks and following the curve of the bentside suggest that Dulcken came under Stein's influence before 1783 when Stein changed from this construction to a so-called A-frame for his pianos.

Adam Achatius Schiedmayer (1745-1817)

{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1103, 1797

Johann David Schiedmayer (1753-1805)

{Munich}	Bayerisches Nationalmuseum, Munich, Inv. No. BNM MU 77, 1785
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1102, 1794
{Erlangen}	Sammlung historischer Musikinstrumente des Musikwissenschaftlichen Instituts der Universität Erlangen-Nürnberg, Erlangen, Inv. No. R14, c.1795*
{Germany 1}	Privately owned in Germany, 1801
{Germany 2}	Privately owned in Germany, 1783

Details of {Erlangen} were taken from *Quellenkataloge zur Musikgeschichte Nr.25*, ed. Richard Schaal, *Sammlung historischer Musikinstrumente des Musikwissenschaftlichen Instituts der Universität Erlangen-Nürnberg* by Thomas Jürgen Eschler, Wilhelmshaven 1993.

Gebrüder Gräbner
(Johann Gottfried 1736-1808, Johann Willem (1737-1798)

{Italy}	Privately owned in Italy, 1791*
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1106, 1793
{U.S.A.}	Privately owned in the U.S.A., 1793
{Halle}	Händel-Haus, Halle, Inv. No. MS-31, 1794

This list is complete. The author is grateful to Kerstin Schwarz for details of {Italy}.

Johann Schmidt (1757-1804)

{Nuremberg 1}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1100, 1789
{Salzburg 1}	Museum Carolino Augusteum, Salzburg, Cat. No. B 15/9, 1794
{Washington}	National Museum of American History, Smithsonian Institution, Washington, U.S.A., Cat. No. 303,537, c.1795
{Nuremberg 2}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1127, c.1795
{Nuremberg 3}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 100, c.1795
{Nuremberg 4}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MIR 1106, c.1795
{Halle}	Händel-Haus, Halle, Inv. No. MS-28, c.1795
{New York}	Metropolitan Museum of Art, New York, Acc. No. 89.4.3182, c.1795
{Salzburg 2}	Museum Carolino Augusteum, Salzburg, Cat. No. B 15/10, 1803

There are more grand pianos by Schmidt. For a more complete list see Kurt Birsak 'Klaviere im Salzburger Museum Carolino Augusteum' in *Salzburger Museum Carolino Augusteum, Jahresschrift* Band 34/1988, Salzburg 1990, 12-3, from which some details of the two Salzburg pianos were taken.

Edmund Ignaz Quernbach (Dates unknown)

{Halle}	Händel-Haus, Halle, Inv. No. MS-29, c.1795

Melchior Quante (Dates unknown)

{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 114, c.1795

Franz Jakob Späth *und* Christoph Friedrich Schmahl (1714-1786, 1739-1814)

Tangentenflügel

{Halle}	Händel-Haus, Halle, Inv. No. MS-30, c.1785
{Vermillion}	Shrine to Music Museum, South Dakota, U.S.A, Cat. No. 4145,c.1785
{U.S.A.}	Private ownership, U.S.A., c.1785
{Vienna}	Kunsthistorisches Museum, Vienna, c.1785

Other *Tangentenflügel* by Späth *und* Schmahl are known.

C. F. Schmahl (1739-1814)

Tangentenflügel

{Leipzig}	Musikinstrumenten-Museum, University of Leipzig, Inv. No. 211, 1790
{The Hague}	Haags Gemeentemuseum, The Hague, Inv. No. 0011-1991,1791
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 98, 1794
{London}	Privately owned in London, c. 1795
{Bad Krozingen}	Collection Neumayer, Bad Krozingen, Cat. No. 19, 1801

Pianos

{Halle}	Händel-Haus, Halle, Inv. No. MS-34, 1804
{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 127, 1809

Other *Tangentenflügel* by Schmahl are known. Some of these are wrongly attributed to Schmahl and his father-in-law Späth.

C. F. Schmahls *Söhne*

{Nuremberg}	Germanisches Nationalmuseum, Nuremberg, Inv. No. MINe 102, 1814

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CHAPTER I

INTRODUCTION

The intended pitch of a piano and the materials, diameters and lengths of its strings are inextricably linked to each other. Taken together they form the most crucial aspect of piano design. The material, thickness and length of a string govern not only its pitch but also the possible volume and quality of the sound produced. The string lengths also determine the layout of the instrument. It is obvious that the longer the strings of the lowest notes, the longer the piano. But the scaling, a collective term referring to the complete set of string lengths (or part of that set), also determines other features of the design such as the curve of the bridge and hence the overall shape of the instrument. The tension of the strings is determined by the pitch to which the instrument is tuned, the scaling, the thicknesses and materials of the strings and the number of strings for each note. The total tension must be taken into account in the design of the case structure. The tension to which each string is subjected when at the desired pitch must not be too close to the breaking tension of the string; a reasonable safety margin must be allowed.

It should be mentioned at the outset that one aspect of stringing, the position along the string at which the hammer strikes, is not discussed here. A comparison of the so-called strike points of the pianos measured for the present research has yielded no significant conclusions and has shown that strike points are neither characteristic of particular builders nor of schools of building.[1]

This essay comprises a survey of the stringing, scaling and pitch of the grand pianos of builders active in the Viennese and southern German traditions between about 1785 and 1820.[2] The firms founded by Johann Andreas Stein and Anton Walter

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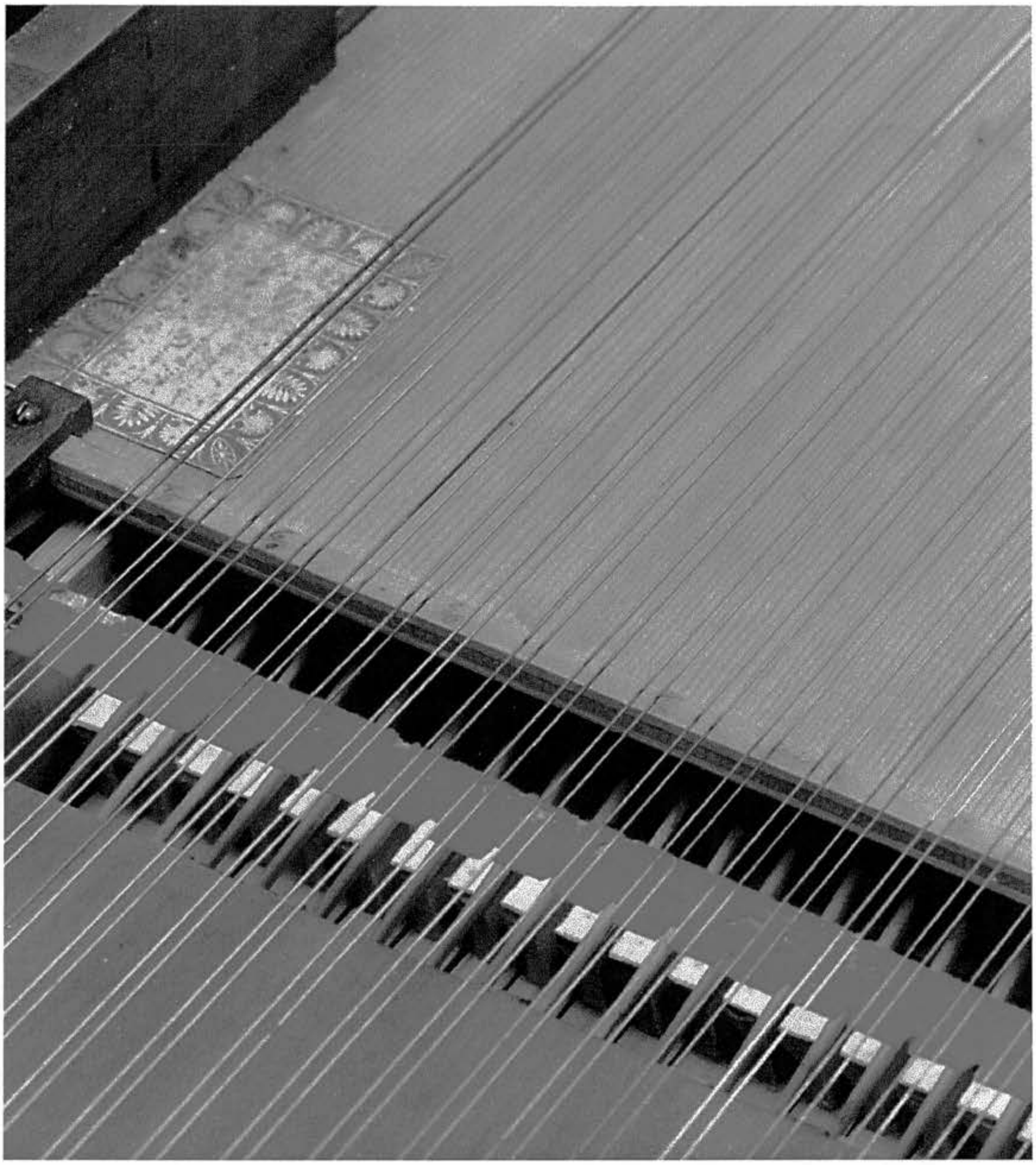
1 Robert S. Winter's contention in his article 'Striking it Rich: The Significance of Striking Points in the Evolution of the Romantic Piano', *Journal of Musicology*, VI/3, 1988, 267-92 (esp. 283) that English and Viennese pianos can be distinguished on account of their strike points is based on a very small sample and cannot be sustained when, for instance, a number of early pianos by John Broadwood (from between 1787 and 1796), are compared with the pianos of the Viennese makers Anton Walter and Ferdinand Hofmann. Similarly, Eva Badura-Skoda's contention that there is a clear difference between the pianos of Johann Andreas Stein on the one hand and those of Anton Walter and Johann Schantz on the other with regard to their strike points (Eva Badura-Skoda, 'Prolegomena to a history of the Viennese Fortepiano', *Israel Studies in Musicology*, 2, 1980, 77-99, esp. 96) can not be sustained when the strike points of the instruments of these makers are actually compared. Konstantin Restle, in *Bartolomeo Cristofori und die Anfänge des Hammerclaviers*, Munich 1991, proposes a single value, calculated using the string lengths and strike points or plucking points, the M_pl_{ss} value, which should enable us to distinguish harpsichords from pianos in situations in which this is not clear (see esp. p. 155ff; the reader wishing to test the formula for the M_pl_{ss} value should be warned that it is given incorrectly on page 155: by Restle's own definition, the log function, ln, should come before 1/n, not after as printed). According to Restle, a relatively low M_pl_{ss} value indicates a harpsichord and a relatively high M_pl_{ss} value a piano. I have calculated this value for all the pianos of Hofmann. The later pianos have relatively low M_pl_{ss} values while the earlier instruments have relatively high M_pl_{ss} values. One would at least expect them to be the other way round. The M_pl_{ss} value appears to be of little use to organology. Strike points appear to have largely been dependant on standard positions for the nut pins in relation to the front (player's) edge of the wrestplank and independant of the string lengths.

2 The square pianos built in these traditions are not discussed here. These smaller instruments, in which the strings run in a direction more or less at right angles to that of the key levers, developed out of the clavichord building tradition. Such instruments require a different, separate and appropriate treatment.

dominated these traditions in the last decades of the eighteenth century and at the beginning of the nineteenth century. Special emphasis is placed on their instruments. In addition to the instruments of these two firms, the pianos of Hofmann have been selected both because of his importance as one of the first Viennese makers to use a *Prellmechanik* with an escapement mechanism, probably invented by Stein, and because an unusually large and representative proportion of his surviving grand pianos, including some made as early as about 1785 and one as late as about 1820, have what appear to be their original string gauge markings, sometimes called string numbers (ill. 1). In general, such gauge markings, when present, are found written or stamped on the wrestplank, the soundboard or on the bridge. They indicate the thicknesses of the strings intended for the instrument. In general, the interpretation of these gauge markings in conjunction with an assessment of scaling forms the basis of an understanding of stringing practice.



ill. 1 String gauges marked along the front edge of the soundboard of a piano by Ferdinand Hofmann, c.1790 (private ownership, The Netherlands)

Unlike the pianos of Hofmann, only one of the seventeen surviving pianos by Stein has a complete set of string gauge markings. A small number of early but important instruments by Stein's daughter, Nannette Streicher, who continued the firm after her father's death, also have no string gauges marked. Of about thirty pianos by the Walter firm, only six have complete sets of gauge markings. So by contrast, the string gauge markings on the pianos of Hofmann provide not only clear but also unusually complete information. On the other hand the pianos of Hofmann, of Walter and of the majority of the other relevant builders were not dated by their makers whereas the pianos of the Stein firm, later to become the Streicher firm, were almost all inscribed with a date. The pianos of Stein and Streicher thus provide a reliable chronological background against which the data relating to the pianos of other builders can be assessed.[3]

The scope of the present survey

The present survey covers all the known instruments by Stein, who died in 1792, and most of the surviving instruments made by the Streicher firm before 1823, the year in which Nannette Streicher's son Johann Baptiste became a member of the family firm. All the grand pianos by Hofmann, made between about 1785 and 1820, are included. All but two of the grand pianos by Walter

3 One instrument by Walter, privately owned in Italy, is dated 1796.

made before his stepson Joseph Schöffstoß joined the firm in about 1800 and most of those inscribed *Walter und Sohn*, which date from between about 1800 and 1820, are also included. A considerable selection of the pianos of the followers of Stein and Walter are used to provide auxiliary and substantiating data. A number of pianos by important makers such as Johann Schantz and Johann Jakob Könnicke, who cannot be placed in the school of either Walter or of Stein and who also worked around the turn of the century, are included. In some situations, notably for the pianos of the Streicher firm, excursions in time have been made beyond 1820 for the sake of clarity and interest. It will be remarked that only a very few instruments by the renowned Conrad Graf (1782-1851) have been included here. Although he too was one of the most significant Viennese piano makers of the nineteenth century he was of the next generation after Ferdinand Hofmann (1756-1829), Nannette Streicher (1769-1833) and Anton Walter (1752-1826) so that his instruments fall outside the main period dealt with here.

The codes used in the text for the pianos surveyed

For reference purposes, each of the pianos made by or ascribed to Hofmann, Stein, Streicher and Walter mentioned in the text has been assigned a code. These begin with the capital letter H for pianos by Hofmann, S for those by Stein or the Streicher firm and W for those instruments inscribed *Anton Walter* or *Walter und Sohn* and for those ascribed to the Walter firm. The adoption of the single letter S to cover all the instruments made by Stein and the Streicher dynasty serves to emphasize the continuity of the Stein-Streicher firm. Each of the instruments bearing the name Stein or Streicher can best be understood as a product of the workshop of the firm of piano builders founded by Stein and continued under his daughter, her son and grandson rather than as the work of one particular member of the family. Similarly, the single letter W to indicate instruments made by the Walter firm both before and after about 1800, when Walter's stepson Schöffstoß joined the firm, stresses the artificiality of distinguishing between instruments bearing the name *Walter* and those bearing the name *Walter und Sohn*.

In the codes for the pianos of these major firms the letter S, H or W is followed by the date or approximate date of manufacture. Approximate dates are indicated by 'c.' for *circa*. Lower case letters after the dates differentiate the instruments by the same maker of the same date or approximate date. All the instruments by Stein except one are dated, although some of the dates on the soundboard labels of his instruments do not agree with the dates which, in some pianos, are found written inside the case, either on the baseboard or on the underside of the soundboard.[4] The presence of these dates was discovered by Reinhardt Menger. In the instances in which they occur, the dates inside the case have been respected here in preference to those on the soundboard labels. The dates inside are presumed to have been written while the instruments were being made. The labels, on the other hand, can easily be altered or faked and this has indeed happened in some pianos.

Stein died on February 29th 1792, three months after Mozart. Thereafter, Stein's son Matthäus Andreas and daughter Nannette worked together to maintain the family business. They separated in 1802. Neither the pianos they made together, nor those made by Nannette after 1802 and prior to 1805 are dated. After 1805 both the date and the firm's opus number are usually found in numerous places on the instruments of the Streicher firm. In the codes for these pianos the *opus* numbers have been included after the date.

Neither Hofmann nor Walter used *opus* numbers, although many of Hofmann's instruments have a number written on the front vertical face of the wrestplank. These numbers were probably used to distinguish different instruments made

4 The earliest instrument by Stein is S/1777, the *vis-à-vis* instrument in Verona. The soundboard label, now lost, was inscribed with the date 1777. There appears to be no reason to doubt this date. See Michael Latcham, 'The Pianos of Johann Andreas Stein', *Studien zur Aufführungspraxis und Interpretation der Musik des 18. Jahrhunderts*, Michaelstein, November 1996, 14-49.

concurrently and are certainly not indicative of date. There are three pianos bearing the number 1 and two with the number 5.

Some of the pianos of Johann Schantz also have numbers written on the damper rail, the action and elsewhere. By chance, two pianos numbered 89 have survived and it seems likely that the numbers on Schantz's piano refer to the production of a single year. At the beginning of the nineteenth century it was not unusual for a piano building firm in Vienna to make a hundred instruments yearly. Direct evidence relating to Schantz comes from a letter of 1803 written by Georg August Griesinger to the publishers Breitkopf & Härtel in Leipzig:

> 'I have just come from Mr. Schanz. Schanz is very sought after and in the last year has made 130 instruments, although he probably sub-contracted many of them out to former apprentices, something which never happens at Streicher's.'[5]

All the undated pianos by Hofmann and Walter and the few undated ones by Stein and Streicher have been assigned dates on the basis of a large number of features and measurements including the data on stringing and scaling presented here.

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5 '[...] *Ich komme so eben von Herrn Schanz;* [...] *Schanz sehr gesucht, hat im letzten Jahre 130 Instrumente verfertigt, darunter wohl auch manche die er ausser der Werkstätte von ehemaligen Gesellen machen lässt, was bei Streicher nie geschieht*'.' Otto Biba, ed., *"Eben komme ich von Haydn..." Georg August Griesingers Korrespondenz mit Joseph Haydns Verleger Breitkopf & Härtel 1799-1819*, Zürich 1987, 211. I have not standardised spellings when transcribing and translating original texts. Schantz is sometimes given with a t, sometimes not. Nannette Streicher signed herself Nannette but is sometimes referred to as Nanette. The highest number so far found on a piano by Schantz is 124 (Sz/9).

Although the estimated dates are probably accurate to within five years earlier or later, they remain conjectural.[6] In general, these approximate dates are most useful as a means for indicating the chronological position of an instrument relative to that of another by the same maker: c.1782 indicates that the piano concerned is to be regarded as earlier than one by the same maker assigned the date c.1785.

The following examples for the pianos of the firms of Stein, Streicher, Hofmann and Walter should suffice to make the codes clear:

S/1783c indicates one of at least three pianos dated 1783 by Stein;

S/1807/733 indicates the piano by Nannette Streicher which bears the date 1807 and the production number 733;

H/c.1785b indicates one of at least two pianos built by Hofmann in about 1785;

W/c.1815f indicates one of at least six pianos built by Walter in about 1815.

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6 On this subject see Michael Latcham, 'Problems of dating and authenticating Viennese and South German pianos of around 1800, illustrated by a comparison of four pianos, one by Johann Andreas Stein, one by his daughter Nannette Streicher, and two by his pupil, Franz Joseph Wirth', *Harpsichord and Early Piano Studies*, ed. Charles Mould, 113-51, Hebden Bridge, to be published.

The pianos by makers other than Stein, Streicher, Hofmann and Walter referred to in the text have also been assigned codes. Pianos by Schantz have the codes Sz/1 to Sz/22, those by Johann Fritz have been assigned codes from F/1 to F/8 and those by Johann Jakob Könnicke the codes K/1 to K/7. The pianos by other makers are each simply referred to by the name of the maker and the present location of the instrument. The location is given thus {England}. Where appropriate, the dates or approximate dates have been added to the codes in the text. It should be stressed that the same degree of accuracy is not claimed for the dates given for the undated pianos of these secondary makers as for the pianos by Stein, Streicher, Walter and Hofmann.

All 247 instruments mentioned by code, together with their present whereabouts and museum inventory number, if appropriate, are given in a list above, to be found before the beginning of the main text. All but 33 of these instruments have been examined and measured by the author. In addition, six grand pianos by the English firm founded by John Broadwood have been examined and measured by the author to provide comparative material. The earliest of these pianos is dated 1787 and the latest 1823.

Some aspects related to the stringing of a few instruments, notably S/1788b, S/c.1790, S/1816/1117, S/1816/1147, W/c.1782e, W/c.1785b, W/c.1800c, W/c.1800d and W/c.1815b, have not been included in all the comparisons presented here. These instruments all have later soundboards many of which are recent. Much of the data these pianos present cannot be assumed to reflect their original states.[7] This especially applies to their scalings.

As yet it has not been possible for the author to examine two of the pianos inscribed Anton Walter. One of these is in the Rector's Palace in Dubrovnik and the other, which has a recent soundboard and action, is in private ownership in Switzerland. Some extant instruments of the Walter firm built after Walter's stepson joined in about 1800, those inscribed *Walter und Sohn*, have also not yet been examined by the author.

While the majority of the existing instruments by the Streicher firm made before 1830 have been examined and measured for this study, the details of a few have been gleaned from other sources and not directly from the instruments themselves.

In the list of instruments, those pianos included in the survey but not examined by the author are marked with an asterisk. Measurements and data which have not been collected by the author but are given in the text or tables in relation to specific instruments have also been marked with an asterisk.

7 See Michael Latcham, 'Soundboards Old & New', *Galpin Society Journal*, XLV, 1992, 50-8 for a discussion of soundboard replacement.

Stein, Streicher, Walter and Hofmann: biographical notes[8]

Stein was born in Heidelsheim in 1728 and died in Augsburg in 1792 (ill. 2). He settled in Augsburg in 1750 as a maker of keyboard instruments. He was also the organist in the *Barfüßer* church there, playing the magnificent organ which he himself built. Sadly, it was destroyed in a bombing raid during the second world war. Stein was the most famous instrument maker of his day and his reputation became legendary after his death. In the obituary for his daughter Nannette in the *Allgemeine musikalische Zeitung* No. 23 of 1833 we read

> 'Nannette Stein was born in Augsburg on January 2nd 1769. Her father was Andreas Stein, famous, and quite rightly so, as a thorough keyboard player and organist, as the builder of one of the most wonderful organs, as the inventor of an action which transformed the raw pantalon into the pianoforte which has now become established everywhere.'[9]

Mozart's letter of 1777 to his father, reporting on a visit to Stein in

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8 Many details of this section are taken from Helga Haupt, 'Wiener Instrumentenbauer von 1791 bis 1815', *Studien zur Musikwissenschaft*, xxiv (1960) and from H. Ottner, *Der Wiener Instrumentenbau 1815-1833*, Tutzing 1977.

9 '*Nannette Stein war geboren zu Augsburg am 2ten Januar 1769. Ihr Vater war Andreas Stein, mit vollem Rechte berühmt als gründlicher Klavier- und Orgelspieler; als Erbauer einer der herrlichsten Orgeln, als Erfinder einer Mechanik, die den rohen Pantalon in das, jetzt überall eingeführte Pianoforte umwandelte;* [...].' *Allgemeine musikalische Zeitung*, June 5 1833, 373-80. '*Pantalon*' probably refers to the keyed dulcimer not the hammer dulcimer for which Hebenstreit was so famous at the beginning of the eighteenth century.

Augsburg contains the best known praise of Stein's pianos:

> 'Before I had seen the work of Stein, Späth's *Clavier* were my favourites; now, however, I must give my preference to Stein's.'[10]

10 '*Ehe ich noch vom stein seiner arbeit etwas gesehen habe, waren mir die spättischen Clavier die liebsten; Nun muß ich aber den steinischen den vorzug lassen* [...].' *Mozart. Briefe und Aufzeichnungen II, 1777-1779*, ed. W. A. Bauer and O. E. Deutsch, Kassel, Basel, London, New York 1962, 68. The punctuation and spelling including the use of upper and lower case are given here, as elsewhere, as in the original source.

ill. 2 A portrait, probably of Johann Andreas Stein as a young man. Oil painting by an unknown artist (private ownership, Germany)

Stein's daughter Anna Maria, known as Nannette, was born in Augsburg in 1769 (ill. 3). She began to take part in the practical activities of the workshop when only ten years old, even making some parts of the pianos.[11] Nannette had already taken over the responsibility of building the pianos in her father's workshop before he died. In her professional life she was one of the most famous piano makers of her day and in her private life she showed herself to be a caring person. From her correspondence with Beethoven it is clear that he could often rely on her for his personal needs. Her care of her father during the last years of his life was praised in her obituary.

> 'During the last years of his illness, it was apparently not enough for her to complete the commissioned work during the day; she shared the distress of his sleepless nights with him, speaking words of comfort to him and raising his spirits if the terror of his hydropsy threatened to reduce him to despair.'[12]

After Stein's death in 1792 his widow appears to have retained the firm for two years under her husband's name and the pianos were still inscribed with Stein's name, '*Jean André Stein*'.[13] In 1794

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11 ' [...] *und er* [Stein] *sie* [Nannette], *in ihrem 10ten Jahre schon, erst zur Verfertigung einzelner Theile der damaligen Mechanik, so wie endlich, zum Einrichten der Tastaturen, zum Stimmen, und gänzlicher Vollendung, seiner Pianoforte mit freundlichstem Ernste anhielt.' Allgemeine musikalische Zeitung,* June 5 1833, 374.

12 *'Es schien ihr während der letzten Jahre seiner Krankheit nicht genug, am Tage die bestellten Arbeiten verfertigt zu haben, sie theilte auch seine schlaflosen Nächte mit ihm und sprach ihm Trost und Ermunterung zu, wenn die Beängstigungen einer Brustwassersucht ihn zur Verzweiflung bringen wollte.' Allgemeine musikalische Zeitung,* June 5 1833, 375.

13 The use of French was a fashionable habit at the time.

Nannette married Andreas Streicher and together with her younger brother Matthäus Andreas, then eighteen years old, moved to Vienna where they continued the business. Instruments from this period are inscribed '*Frère et Sœur Stein*' or '*Geschwister Stein*'. Relations between Nannette and Matthäus Andreas became strained and in 1802 they split up, each continuing to build pianos but under their own names.[14] Nannette then inscribed her pianos '*Nannette Streicher, née Stein à Vienne*'. Her son Johann Baptist, who had already worked in the firm since 1812, joined as a partner in 1823. He was then twenty-seven. Both Nannette and Andreas Streicher died in 1833. The firm continued after the death of Johann Baptiste in 1871 under his son Emil Streicher. In 1896 the firm ceased production. Emil had joined the firm in 1857 when he was twenty-two years old. He died in 1916.

14 See for instance Otto Biba (ed.), *"Eben komme ich von Haydn..." Georg August Griesingers Korrespondenz mit Joseph Haydns Verleger Breitkopf & Härtel 1799-1819*, Zürich 1987, 207 for evidence of the wrangling which was still going on between the siblings in 1803.

ill. 3 Nannette Streicher, *née* Stein: oil painting by an unknown artist (Kunsthistorisches Museum, Vienna)

Walter was born in Neuhausen near Stuttgart in 1752 and died in Vienna in 1826 (ill. 4). He must have already moved to Vienna by 1780; his marriage with widow Schöfstoß was recorded in Vienna in that year. His fame as a piano maker in Vienna became established in the 1790's. Johann von Schönfeld, discussing the piano in his *Jahrbuch der Tonkunst von Wien und Prag* of 1796 wrote:

> 'The artist who has as yet made himself the most famous and who, at the same time, was the first to create this instrument here is Mr. Walter.'[15]

In a letter of 1802 to Court Secretary Nikolaus von Zmeskall, asking him to obtain a piano from Walter, Beethoven expressed impatience with Walter but at the same time a preference for his pianos:

> 'You can give him [Walter] to understand that I will pay him 30# [ducats], even though all the others would charge nothing.'[16]

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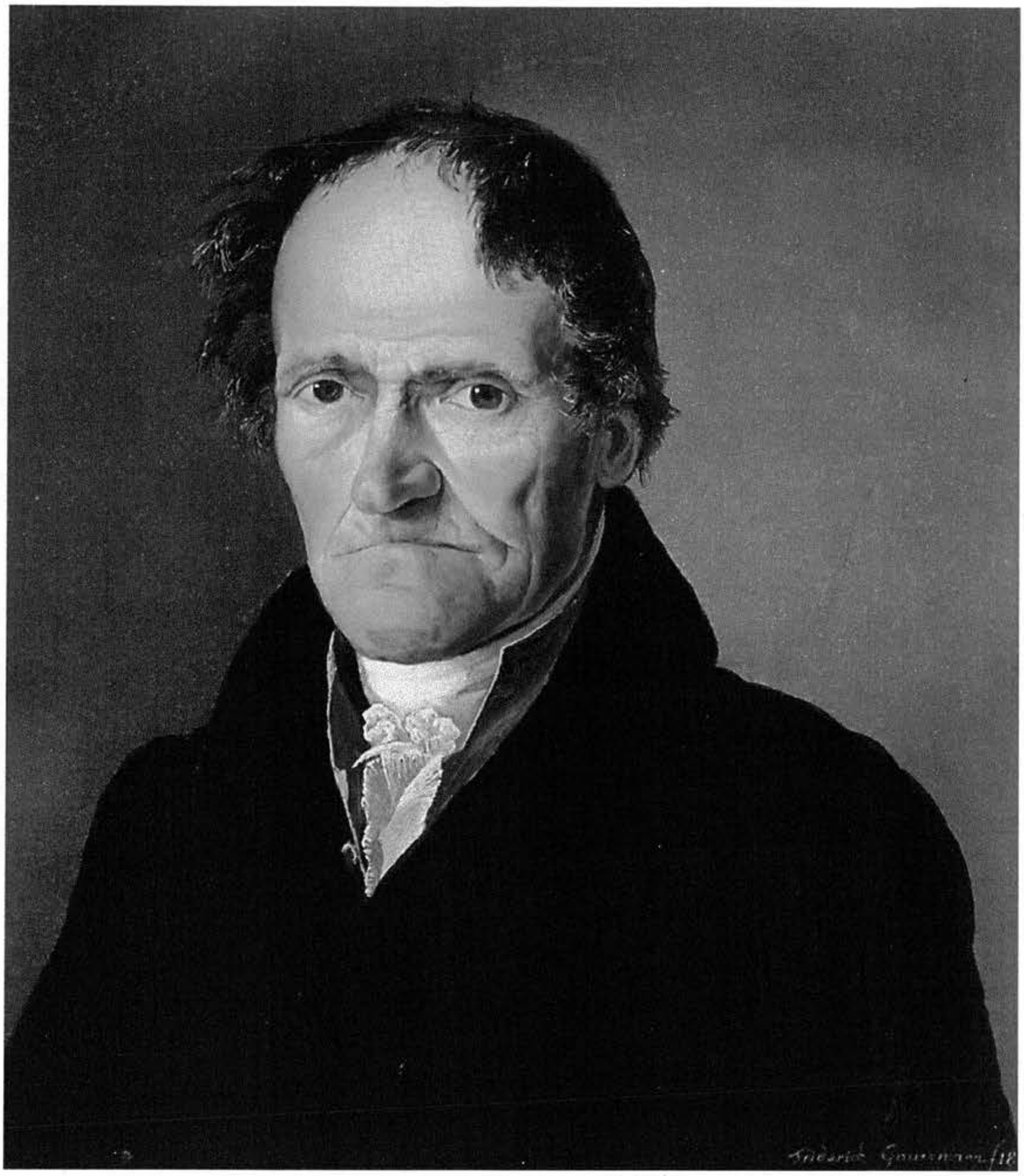
15 '*Derjenige Künstler, der sich bisher am berühmtesten gemacht hat, und der gleichsam der erste Schöpfer dieses Instruments bei uns ist, ist Hr. Walter*[...].' Johann Ferdinand von Schönfeld, *Jahrbuch der Tonkunst von Wien und Prag*, Vienna 1796, facs. Munich & Salzburg 1976, 87-8.

16 '[...] *sie geben ihm also zu verstehen, daß ich ihm 30#* [Dukaten] *bezahle, wo ich es von allen anderen umsonst haben kann* [...] .' Alfr. Chr. Kalischer, ed., *Beethovens Sämtliche Briefe. Kritische Ausgabe mit Erläuterungen*, I, Berlin & Leipzig 1906-7, 105.



ill. 4 Gabriel Anton Walter: oil painting by Friedrich Gauermann, 1825 (Kunsthistorishes Museum, Vienna)

Little is known of Ferdinand Hofmann. He was born in Vienna in 1756 and died there in 1829. In 1784 he obtained the title *Bürger in Wien*, giving him citizenship of Vienna and officially allowing him to sign his instruments. He became *Vorsteher der bürgerlichen Orgel und Clavier Machers* (Chairman of the municipal organ and piano makers) in 1808 and was granted the title *Kaiserlicher und Königlicher Hof Kammer Instrumentenmacher* (Imperial and Royal court chamber instrument maker) in 1812. He was not married but acted as the guardian for the children of his neighbour Ignatz Kober, another well-known piano maker.

ill. 5 A piano by Ferdinand Hofmann, c.1790 (private ownership, The Netherlands)

Photo: Theo Strengers

The organisation and production of the workshops

Not much is known of how the workshops of Stein and Nannette Streicher were organised. From an entry in the diary Dr. Karl Bursay we know that Nannette was the foreman in her workshop, rather than Andreas Streicher, her husband. Bursay briefly described Nannette Streicher:

> 'Already at her father's in Augsburg her exceptionally great love of music inspired her to learn to build instruments. At the time of her marriage she was truly the one who actually did the work in the atelier.'[17]

Bursay continues:

> 'His workshop [the workshop of Andreas Streicher to whom Nannette was married] is very extensive and occupies a large part of the house in which he only has a few rooms as living quarters. At present, the firm N. Streicher *née* Stein is already working on instrument no. 1152.'[18]

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17 *'Sie lernte schon in Augsburg bei ihrem Vater aus übergrosser Liebe zur Musik Instrumente machen und war bei ihrer Verheiratung auch wirklich die eigentlich Wirkende in der Werkstatt.'* From Dr. Karl Bursay's diary, quoted in Otto Clemen, 'Andreas Streicher in Wien', *Neues Beethoven-Jahrbuch*, IV, 1930, 111.

18 *'Seine* [Streicher's] *Werkstatt ist sehr ausgedehnt und nimmt ein grosses quarree Haus ein, worin er nur wenige Zimmer zu seiner Wohnung hat. Unter der Firma N. Streicher nee Stein wird jetzt schon das 1152. Instrument gearbeitet'.'* From Dr. Karl Bursay's diary, quoted in Otto Clemen, 'Andreas Streicher in Wien', *Neues Beethoven-Jahrbuch*, IV, 1930, 112. Both Bursay and Beethoven appear to have seen fit to refer to Andreas Streicher rather than Nannette as the piano builder. Beethoven, in his letters to Nannette, never discusses matters of piano building with Nannette and even goes so far as to ask her to ask her husband about a piano. Exactly how this apparent disrespect for her craftsmanship should be interpreted is, however, probably a matter of understanding the social form of the day.

The Streicher firm produced some 9000 pianos during the century of the firm's existence. Of these instruments, between 150 and 200 have survived, representing only about 2% of the total production. On graph 1 the *opus* numbers of the firm's pianos are plotted against date of manufacture. Of approximately 2000 made before 1825, about 30, or just less than 2%, have survived.

A similar calculation can be made for the Schantz workshop (in operation between about 1790 and 1825) on the basis of the remark made by Griesinger:

> 'I have just come from Mr. Schanz. Schanz is very sought after and in the last year has made 130 instruments, although he probably sub-contracted many of them out to former apprentices, something which never happens at Streicher's.'[19]

Of about 3000 instruments made in the Schantz workshop (or indeed in the workshops of his sometime apprentices) about 40 survive, again something less than 2%.

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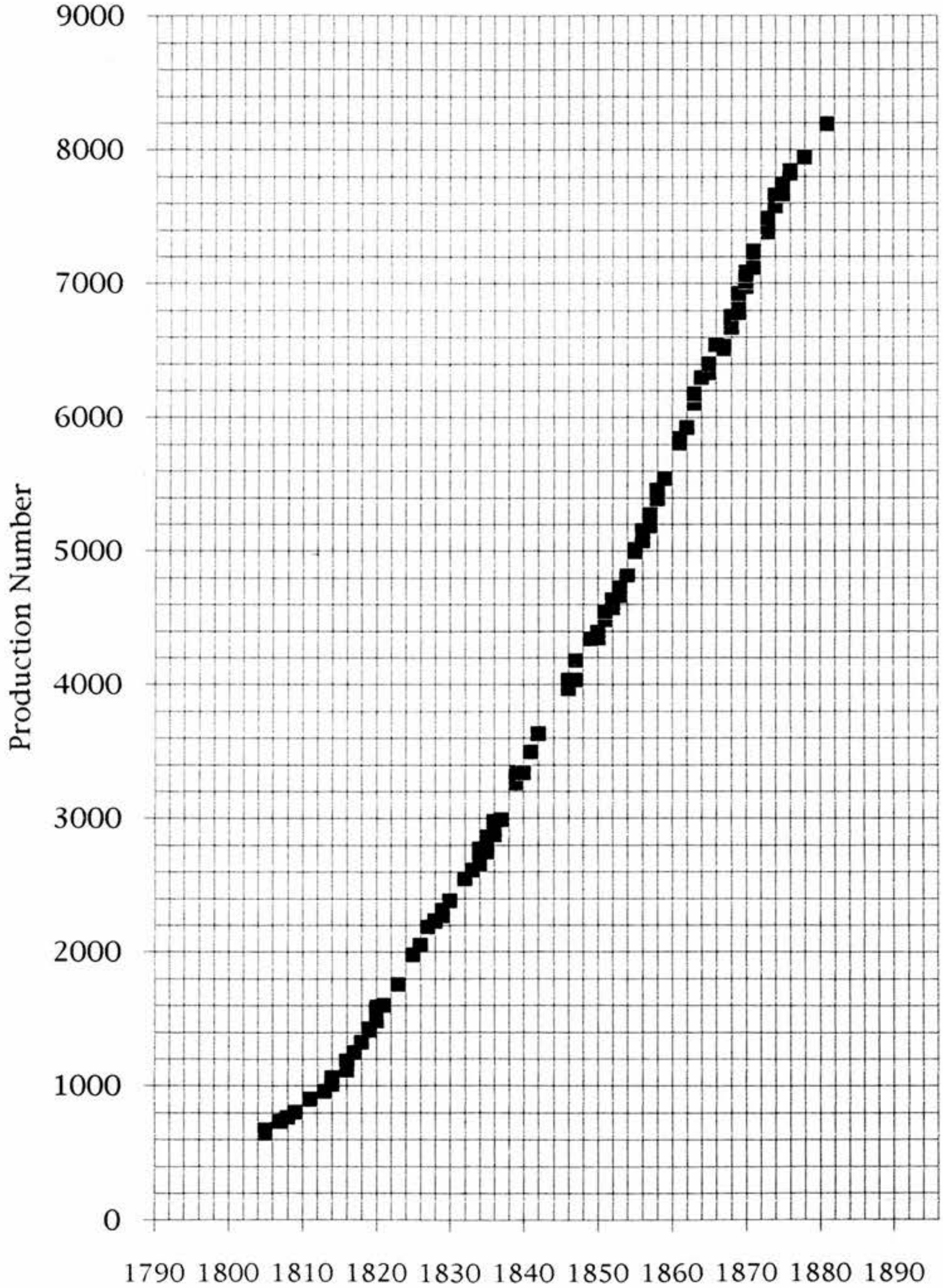
19 '[...] *Ich komme so eben von Herrn Schanz;* [...] *Schanz sehr gesucht, hat im letzten Jahre 130 Instrumente verfertigt, darunter wohl auch manche die er ausser der Werkstätte von ehemaligen Gesellen machen lässt, was bei Streicher nie geschieht*.' Otto Biba, ed., *"Eben komme ich von Haydn..." Georg August Griesingers Korrespondenz mit Joseph Haydns Verleger Breitkopf & Härtel 1799-1819*, Zürich 1987, 211.

Pianos made by the Streicher firm
The chronology of the production numbers



graph 1

In a contemporary source, Hofmann, together with his eight workmen, is reported to have made one instrument every week.[20] The firm operated between 1784 and about 1825. One instrument a week may have been an exaggeration, but even assuming a production rate of one piano a fortnight for twenty years, the twenty-four surviving instruments, including three square pianos and one clavichord, represent only about 5% of the total output of the Hofmann firm.

The proportion of pianos by the Walter firm which survives is also small. With up to 20 workmen Walter is reported to have made about three pianos each month.[21] Some 35 pianos by the Walter firm are known, about the total the firm produced in one year alone. The firm operated for about 30 years.

In an extensive article in the second edition of Gerber's *Lexikon*, published in 1814, more than 700 of Stein's instruments are said to be spread throughout Europe.[22] This is repeated with added detail in the sixth volume of Schilling's *Encyclopädie*, published in 1838, where it is said of Stein that he

> 'not only considerably improved the clavichords, harpsichords and fortepianos of the day, bringing them to

20 Josef Rohrer, *Bemerkungen auf einer Reise von der türkischen Gränze über die Bukowina durch Ost- und Westgalizien, Schlesien und Mähren nach Wien*, Vienna 1804, 288.

21 See John A. Rice, 'Anton Walter, Instrument Maker to Leopold II', *Journal of the American Musical Instrument Society*, XV, 1989, 39.

22 '*Von seiner Melodika und seinen Pianofortes sind über 700 in ganz Europa verbreitet.*' E. L. Gerber, *Neues historisch-biographisches Lexicon der Tonkünstler*, iv, Leipzig 1814, 264.

the highest degree of perfection, but he also joined the latter two instruments together in one, and more than 700 examples from his workshop have travelled through the whole of Europe.'[23]

If this is true, then the 20 surviving instruments by Stein, including the two in which a harpsichord and a piano are combined, represent a mere 3% of his total output.

A similar figure can be calculated for Conrad Graf's production. Of some 2800 instruments made, judging from their *opus* numbers, about 70 are known, again between 2% and 3%.[24]

The manufacture of the pianos of all these firms must have been highly efficient, with instruments built in series rather than making a fresh design for each individual piano. If there is a lack of similarity amongst the extant pianos of any one builder it does not follow that each piano of that maker was made as a unique object. A piano unlike any other by the same maker is more likely to be the lone survivor of a series. Conversely, any important similarities shown in the design of a number of the instruments of one maker point towards a high degree of consistency in production and hence, probably, a conservative attitude to design.

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23 '*Er verbesserte nicht nur wesentlich die bisherigen Claviere, Flügel und Fortepiano's zum möglichsten Grade der Vollkommenheit, sondern verband auch die beiden letztgenannten Instrumente in eins zusammen, und mehr vielleicht denn 700 Exemplare aus seiner Fabrik machten die Reise durch ganz Europa.*' Gustav Schilling, ed., *Encyclopädie der gesammten musikalischen Wissenschaften, oder Universal-Lexicon der Tonkunst*, VI, Stuttgart 1838, 479.

24 These figures are extracted from Deborah Wythe, *Conrad Graf (1782-1851) Imperial Royal Court fortepiano maker in Vienna*, Ph.D. dissertation, Ann Arbor 1990.

Whereas the surviving instruments of Walter do not readily fall into groups of consistent design, some features of Hofmann's pianos are the same for all his instruments made between about 1785 and 1815. This contrast between the more innovative Walter and the more conservative Hofmann may explain the reports that Walter made three pianos a month with 20 workmen while Hofmann could produce four instruments a month with eight workmen. Hofmann's firm must have followed well-worn procedures and routines. Walter's pianos, on the other hand, demonstrate that his firm probably made frequent changes to the basic design, and thus in workshop practice, presumably slowing down the production rate.

The exceptional workshop of Johann David Schiedmayer (1753-1805) deserves special mention here. Schiedmayer was a journeyman in Stein's workshop from 1778 to 1781 and therefore may certainly be reckoned as belonging to the school of Stein. Many features of Schiedmayer's surviving instruments are clearly the result of his years in the Stein workshop although others, most notably the incorporation of a moderator, appear to be Schiedmayer's own invention.[25] In Schiedmayer's unpublished notebook only four different apprentices are mentioned between the years 1782 and 1790.[26] One of them, Georg Kohlmann, worked

25 See Sabine Klaus, *Studien zur Entwicklungsgeschichte besaiteter Tasteninstrumente bis etwa 1830. Unter besonderer Berücksichtigung der Instrumente im Musikinstrumentenmuseum im Münchener Stadtmuseum*, Bd. 3, Tutzing 1997, *Hammerflügel*, No. 2, BNM *MU 77*.

26 I would especially like to thank Sabine Klaus for placing a transcript of the notebook at my disposal. The apprentices are mentioned on pp. 15-18.

for Schiedmayer for four different stretches of time, the first and longest of which was from 1782 to 1786.

The list of pianos Schiedmayer built between 1781 and 1799, also given in the notebook, comprises a mere 34 instruments, an average of only about two instruments each year. Schiedmayer is however careful to mention that the pianos on the list were made 'completely alone' meaning, presumably, without help from apprentices or journeymen.[27] Nonetheless, in the second edition of Gerber's *Lexicon* we read that the main reason Schiedmayer moved from Erlangen to Nuremberg in 1797 was that

> 'the only carpenter in Erlangen who could properly make the cases for his instruments moved house from there to Nuremberg.'[28]

It appears then that the making of a case was not counted as part of the making of an instrument proper.

Schiedmayer's small production, in which each instrument was made individually rather than as one of a series, and the more solitary nature of his way of working give a picture of a workshop quite unlike those of Stein, Walter or Hofmann. In this respect Schiedmayer's workshop may not have been exceptional. Perhaps many of the smaller firms in Vienna were similar in size and

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27 '[...] *ganz allein verfertigt* [...]'. notebook, 48.

28 '*Daß der Tischler welcher ihm in Erlangen allein das Korpus zu seinen Instrumenten habe recht machen können, sich von da nach Nürnberg gewendet habe* [...] .' E. L. Gerber, *Neues historisch-biographisches Lexicon der Tonkünstler*, iv, Leipzig 1814, 66-7.

production.

The proportion of the pianos by Schiedmayer which has survived is relatively high in comparison with the small percentages calculated above. Each of the pianos on the list in Schiedmayer's notebook is assigned an *opus* number and usually both the price paid and the name of the buyer are mentioned.[29] At least four of the 34 instruments he made between 1781 and 1799 survive giving the surprisingly high survival rate of nearly 12%. This could be put down to chance but may perhaps be due to the exceptional quality of Schiedmayer's instruments, a quality which deserved special praise in both editions of Gerber's *Lexicon* (1792 and 1814), in Schilling's *Encyclopädie* (1838) and in the *Biographie Universelle* of Fétis (1844).[30]

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29 Two of Schiedmayer's surviving instruments, {Germany 2} and {Nuremberg}, have retained inscriptions inside the case on the baseboard which tally with two entries in the notebook, No. 7 (1783) and No. 30 (1794). In the *Magazin der Musik*, ii, ed. C. F. Cramer (Hamburg, 1784), 127, an instrument by Schiedmayer is mentioned as having left the Schiedmayer workshop on the 5th of December 1783 and that it was sent to Würzburg. This instrument, which must be {Germany 2}, has the date 1783 and 'No. 7' written on the baseboard. It is still owned in Würzburg. {Nuremberg} is inscribed with the date 1794 on a soundboard label. From the notebook we know that Schiedmayer produced only one instrument in 1794 and that it was sold to Professor Mehmel of Nuremberg. The name Mehmel appears on the baseboard inscription inside {Nuremberg}. The latter instrument is decribed by Gerber as the best from Schiedmayer's hand (E. L. Gerber, *Neues historisch-biographisches Lexicon der Tonkünstler*, iv, Leipzig 1814, 67). No inscription is to be found inside {Munich} according to Sabine Klaus (personal communication April 1997). {Germany 1} of 1801 does have an inscription. In the *Magazin der Musik* particular mention is made of the moderator which, in both {Nuremberg} and {Germany 2} is normally on and taken off using a knee lever.

30 E. L. Gerber, *Historisch-biographisches Lexicon der Tonkünstler*, ii, Leipzig 1792, 428; E. L. Gerber, *Neues historisch-biographisches Lexicon der Tonkünstler*, iv, Leipzig 1814, 66-7, *Encyclopädie der gesammten musikalischen Wissenschaften, oder Universal-Lexicon der Tonkunst*, ed Gustav Schilling, vi, Stuttgart 1838,199-200; and F. J. Fétis, *Biographie universelle des musiciens et Bibliographie générale de la musique*, vi,

In the 1780's, before the French Revolution, there had only been a handful of piano makers in Vienna, including Hofmann and Walter.[31] By 1825 there were some 300 firms, including those of Hofmann, Walter and Streicher.[32] On average, each of these firms probably produced at least ten pianos a year, catering for a fast-growing middle class at home and abroad. Of the vast number of pianos made, probably more than 3000 a year in Vienna alone, only a small proportion remains on which to base the conclusions drawn here. This should be remembered throughout the present essay. Nonetheless, it is to be hoped that it is the best instruments which have survived, those made by the makers who set the standards of piano design in their day.

The German and Viennese piano actions

While the differences between the stringing practices of Stein and Walter are not immediately obvious the instruments of the two makers are easily distinguished on account of their actions. The instruments of Stein and Walter have two distinct forms of an action known by its German name, the *Prellzungenmechanik.*[33]

Brussels 1844, 93.

31 In Helga Haupt, 'Wiener Instrumentenbauer von 1791 bis 1815', *Studien zur Musikwissenschaft*, xxiv (1960).

32 H. Ottner, *Der Wiener Instrumentenbau 1815-1833*, Tutzing 1977.

33 '*zungen*' refers to the escapement hoppers or 'tongues'.

This action, generically referred to here as the *Prellmechanik* with an escapement mechanism, is found in most grand pianos built in the southern German and Viennese traditions from about 1790 up to the middle of the nineteenth century. Characteristically, the hammers are mounted on the key levers and the escapement hoppers are hinged on the key frame independently of the key levers. These hoppers enable the hammers to escape from the action train before the player releases his finger.

There can be little doubt that Stein was the inventor of the *Prellmechanik* with an escapement mechanism.[34] The oldest surviving example of this action is found in the piano of the combined organ and piano (S/1781), or *claviorganum*, made by Stein in 1781.[35] The form in which Stein conceived the *Prellmechanik* with an escapement mechanism is called here the German action. In Stein's German action the escapement mechanism includes wooden *Kapseln*, or forks in which the hammers pivot, and vertical escapement hoppers. There is no hammer check to catch the hammers as they return from striking the strings (ill. 6).

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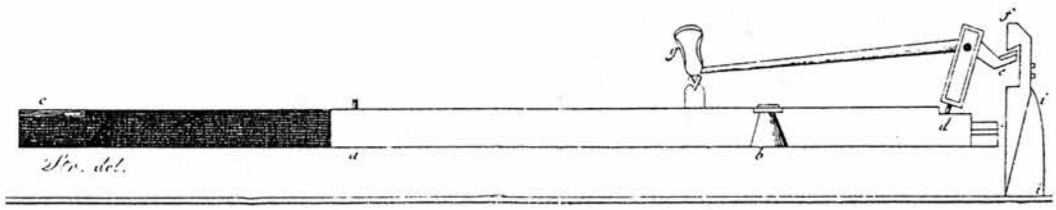
34 See Michael Latcham, 'The Pianos of Johann Andreas Stein', *Studien zur Aufführungspraxis und Interpretation der Musik des 18. Jahrhunderts*, Michaelstein, November 1996, 15-49.

35 This instrument combines an organ with a piano. The term *claviorganum* more often refers to an organ with a harpsichord.



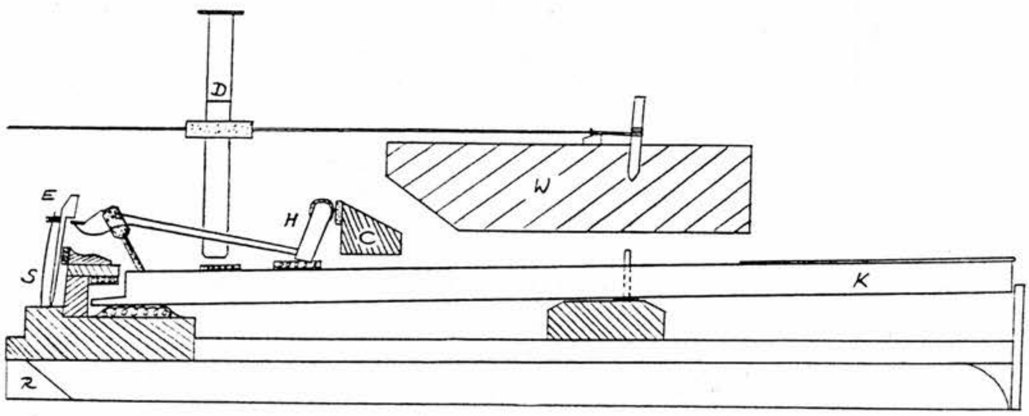
ill. 6 Stein's German action as drawn by Andreas Streicher in the booklet which accompanied the firm's pianos when they were delivered to clients. *f* indicates the vertical escapement hopper, *d* is at the foot of the wooden *Kapsel* and *i* is the return spring for the escapement hopper. The hammer is marked *g*, the hammer beak *e*, the space for the damper *b*, the balance pin *a* and the key plate *c*. There is no hammer back check.

The Viennese action, a more developed form of the *Prellmechanik* with an escapement mechanism, should be distinguished from the German action.[36] In the Viennese action there are three new features. First, the *Kapseln* are of brass and second, the escapement hoppers lean forward (ill. 7). Third, either there is a continuous hammer check serving all the hammers or there are individual checks, one for each hammer. These changes to the German action make a considerable difference to the way the action functions and to how it feels to the player.[37] Walter may have been the first to modify the *Prellmechanik* with an escapement mechanism in these ways. The oldest known instrument with its original action with all three innovations is probably a piano by Walter of about 1785 (W/c.1785a).[38] Mozart's piano (W/c.1782b), also built by Walter, has a similar action now but there is little doubt that it was radically changed by Walter after Mozart's death, leaving the question of the type of action in this particular piano when Mozart owned and played it open to speculation. Similarly, none of those pianos by Walter here dated before 1785 appears to have an original action.

36 See Michael Latcham, 'The check in some early pianos and the development of piano technique around the turn of the 18th century', *Early Music*, XXI/1, February 1993, 28-42.

37 Paul Poletti in 'Understanding the *Prellmechanik*, A Functional Analysis', an unpublished article given as a lecture at Antwerpiano, Antwerp in 1989 pointed out the importance of the forward-leaning hopper.

38 See Michael Latcham, 'Mozart & the pianos of Walter', *Early Music*, XXV/3, August 1997, 382-400 for questions relating to the dating and authenticity of Walter's pianos. Mozart's piano is now in the *Mozart Geburtshaus* in Salzburg.



ill. 7 Walter's Viennese action. D indicates the damper, W the wrestplank, H the hammer, E the escapement hopper, S the return spring for the escapement hopper, C the hammer back check, K the key and R the ramp at the back of the keywell on which the action rests.

Other types of action, including the so-called *Stoßmechanik*, are also found in grand pianos built in southern Germany and Vienna towards the end of the eighteenth century. In the *Stoßmechanik* the hammer is characteristically mounted on a rail independently of the key. A jack mounted in or on the key acts to raise the hammer towards the string when the key is depressed. In the grand pianos with this type of action there is usually an escapement mechanism which disengages the jack from its point of contact with the hammer just before the string is struck, allowing the hammer to escape, strike the string and fall either to a back check, if present, or to rest position, all before the player releases the key. If a true back check is present it is mounted on the key. The *Stoßmechanik* in its most complete form, with both an escapement mechanism and a back check, was invented by Bartolomeo Cristofori (ill. 8).[39] This action was copied, with minor modifications, by Gottfried Silbermann and his nephew Johann Heinrich Silbermann.[40] It is presumably through this route that the *Stoßmechanik* found its way to southern Germany and Vienna.

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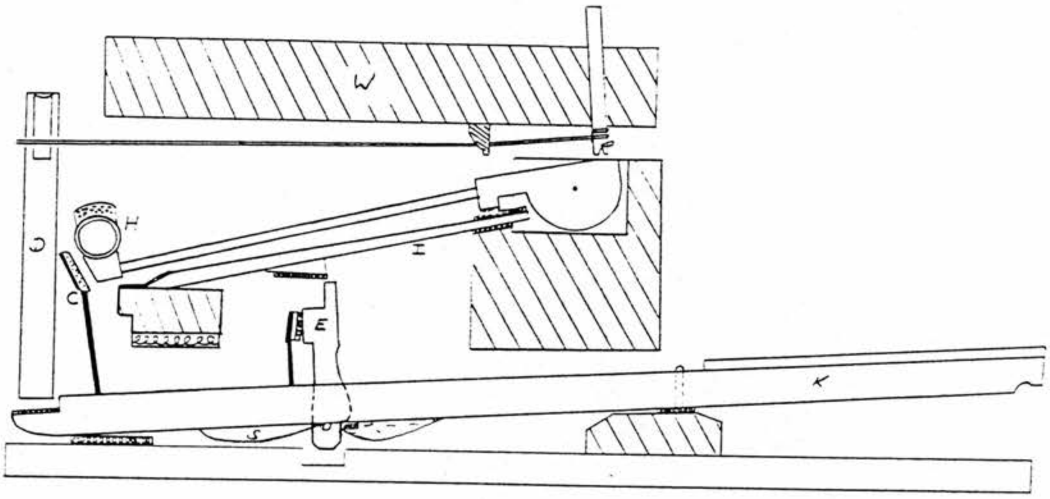
39 See Stewart Pollens, *The History of the Early Piano*, Cambridge 1995, especially chapter 3.

40 See Stewart Pollens, *The History of the Early Piano*, Cambridge 1995, especially chapter 6.



ill. 8 Cristofori's action. D indicates the damper, W the wrestplank, H the hammer, E the escapement jack, S the return spring for the escapement jack, C the hammer back check, K the key and I the intermediate lever.

A few Viennese pianos, notably the *Harmonie Hammerflügel* of 1796 ascribed to Könnicke, three grand pianos ascribed to Ignatz Kober and a square piano inscribed with his name and the date 1788, have survived with what might be regarded as a simplified form of Cristofori's action.[41] These pianos demonstrate that the *Prellmechanik* was not the only type of piano action used in Viennese pianos during the 1780's and '90's. The late eighteenth-century *Tangentenflügel* of Franz Jakob Späth and Christoph Friedrich Schmahl of Regensburg can be regarded as pianos with a *Stoßmechanik* but without an escapement mechanism.[42] An anonymous grand piano presumed to be of southern German origin and dating from about 1785 also has a *Stoßmechanik* without an escapement mechanism.[43] Finally, of three known grand pianos by Mathias Schautz, a pupil of Stein who also worked in Augsburg, the

41 The *Harmonie Hammerflügel* (K/5) has six diatonic keyboards enabling a meantone temperament in practically any key. The pianos by Kober are {Vienna 1}, {Prague}, {Braunau} and {Vienna 2}. The actions of all four lack Cristofori's intermediate lever and have no true back check. A drawing of this action, probably as found in an instrument by Kober and sold by the firm Siemens Andrew is found on page 41, fig. 30 in Rosamund E. M. Harding, *The Piano-Forte, Its History traced to The Great Exhibition of 1851*, Cambridge 1933. Another square piano in the Technisches Museum, Vienna (inv. no. 350) with the same action is attributed to Kober by Sabine Klaus in her unpublished catalogue of the pianos of that museum. In the actions of Cristofori and the Silbermanns there is an additional intermediate lever in the hammer train omitted by such makers as Kober.

42 Elsewhere the author has argued that the *Tangentenflügel* was probably understood as a piano in the late eighteenth century. See Michael Latcham, 'The Pianos of Johann Andreas Stein', *Studien zur Aufführungspraxis und Interpretation der Musik des 18. Jahrhunderts*, Michaelstein, November 1996, 15-49. The action of these *Tangentenflügel* includes an intermediate lever.

43 Now in Nuremberg, Germanisches Nationalmuseum Inv. No. MIR 1123. The hammers are hinged to the front edge of the soundboard. Except for the action little of this anonymous instrument is original.

earliest, of 1792, also has a *Stoßmechanik* but with an escapement mechanism.[44]

The piano in Stein's combined harpsichord and piano of 1777 (S/1770) has a so-called *Zugmechanik* in which the escapement hoppers, attached to the keys, pull down the hammers (ill. 9). The essential configuration of the *Stoßmechanik* is present, however, inasmuch as the hammer activator is hinged to the key and the hammer is mounted in a separate hammer rail. Because this action is intermediate between the action of Johann Heinrich Silbermann and Stein's later German action, one could infer that Stein himself probably built pianos with a *Stoßmechanik*, similar to that in the pianos of J. H. Silbermann, prior to making instruments with the action found in S/1770.[45] Stein was active in the Silbermann workshop in Strasbourg in 1748 and 1749.

Walter may also have made pianos with a *Stoßmechanik*, with or without an escapement mechanism, before turning to the *Prellmechanik*. The later actions in the earliest two pianos by Walter, including the one once owned by Mozart, may be replacements for actions of the *Stoßmechanik* type.[46]

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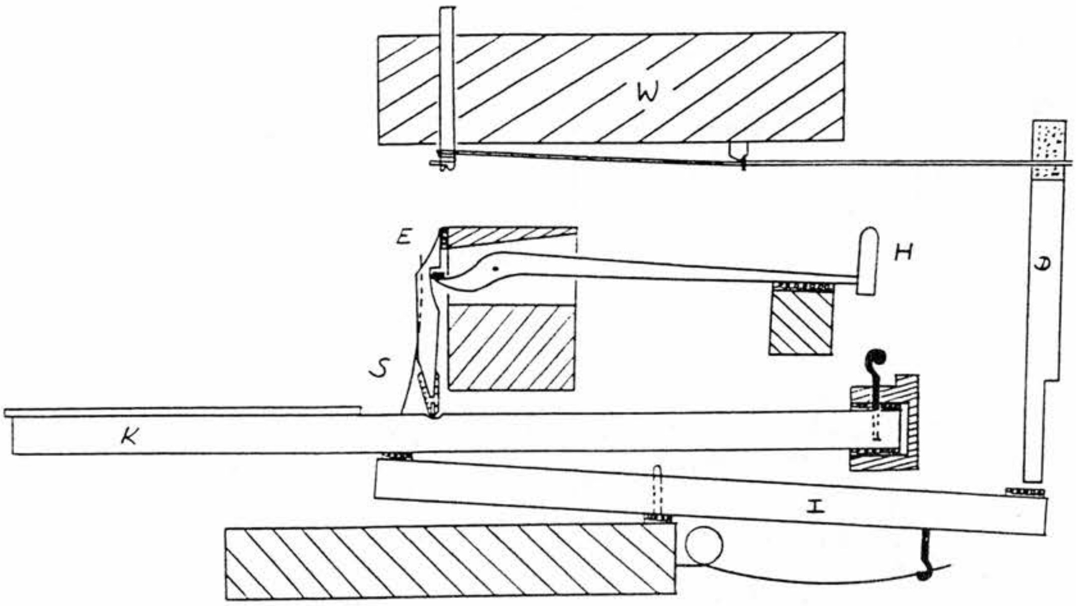
44 See Georg F. Senn, 'Der Klavierbauer Mathias Schautz (1755-1831)', *Glarena*, 46/I, 1997, 3-21. See p.10 for a drawing of the *Stoßmechanik*.

45 S/1777. See Michael Latcham, 'The Pianos of Johann Andreas Stein', *Studien zur Aufführungspraxis und Interpretation der Musik des 18. Jahrhunderts*, Michaelstein, November 1996, 15-49. I am grateful to John Koster for pointing out to me that Stein may have made instruments with an action similar to that on the pianos of Silbermann (personal communication, January 1993).

46 See Michael Latcham, 'Mozart & the pianos of Walter', *Early Music*, XXV/3, August 1997, 382-400. These two instruments by Walter are listed here as W/c.1782a and W/c.1782b.



ill. 9 The piano action in Stein's *vis-à-vis* harpsichord-piano of 1777. D indicates the damper, W the wrestplank, H the hammer, E the escapement jack, S the return spring for the escapement jack, K the key and I the intermediate lever for raising the damper.

This drawing is a modified version of the drawing to be found in: J. H. van der Meer and R. Weber, *Catalogo degli strumenti musicali dell'Accademia Filarmonica di Verona*, Verona 1982, 97.

Although both the *Prellmechanik* and the *Stoßmechanik* are found in pianos made in the southern German and Viennese traditions in the 1780's, the *Stoßmechanik* is only rarely found after 1790.[47] Meanwhile, Stein's German action and Walter's Viennese action, the two forms of the *Prellmechanik* with an escapement mechanism, were both employed in pianos made in Vienna and elsewhere. Stein's German action was used by his daughter until as late as 1805 while Walter had been building pianos with the Viennese action already in about 1785. The two types of piano made by these makers are described by Von Schönfeld in his *Jahrbuch* of 1796:

> 'Because we have two original builders of pianos, we also divide our pianos into two classes: those that are made in the style of Walter and those made in the style of Streicher. By close observation we can also detect two classes of players amongst our best piano players. One of these classes loves a great musical treat, that is, a powerful sound; to that end they play with a rich texture, extremely fast and study the most difficult runs and the fastest octaves. This requires authority and a strong nerve.
>
> 'Such players, whose strength knows no moderation, require pianos that can take any excesses. For the virtuosi of this kind we recommend the Walter style of piano. The other class of player seeks nourishment for the soul and loves playing that is not only clear but also soft and melting. These can choose no better instrument than the Streicher or so-called Stein type. The class between the [two types of] virtuosi will however not be disappointed in finding good instruments to fit every taste and every pocket.'[48]

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47 Besides Könnicke's *Harmonie Hammerflügel* (K/5) one square piano by Schantz also has a *Stoßmechanik* (Sz/1).

48 '*Da wir nun zwei Originalinstrumentenmacher haben, so theilen wir*

Hofmann was one of the Viennese builders whose instruments would have been suitable for the class between the two types of virtuosi. He was one of the small number of the first generation of builders in Vienna to use a *Prellmechanik* with an escapement mechanism. In his action design he steered a middle course, using some elements from the German action and some from the Viennese action.[49] Except for the last two (H/c.1815 and H/c.1820), all his surviving grand pianos have vertical escapement hoppers very similar to those in Stein's instruments. The earliest piano ascribed to Hofmann (H/c.1784a) is also like the instruments of Stein in that there is no back check. The next piano (H/c.1784b) has only a rudimentary check while the following sixteen have checks which would operate under all but the most severe

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unsere Fortepiano in zween Klassen: die Walterischen und Streicherischen. Eben so haben wir auch bei genauer Aufmerksamkeit zwei Klassen unter unsern grössten Klavierspielern. Eine dieser Klassen liebt einen starken Ohrenschmauss, das ist, ein gewaltiges Geräusche; sie spielt daher sehr reichtönig, auserordentlich geschwind, studiert die häckeligsten Läufe und die schnellsten Octavschläge. Hiezu wird Gewalt und Nervenstärke erfordert; diese anzuwenden, ist man nicht mächtig genug, eine gewisse Moderazion zu erhalten, und bedarf also eines Fortepianos, dessen Schwebung nicht überschnapt.

Den Virtuosen dieser Art empfehlen wir ein walterisches Fortepiano. Die andere Klasse unsere grossen Klavierspieler sucht Nahrung für die Seele, und liebt nicht nur deutliches, sondern auch sanftes, schmelzendes Spiel. Diese können kein besseres Instrument, als ein Streicherisches, oder sogenanntes Steinisches wählen. Die Zwischenklasse der Virtuosen werden ausserdem nicht verlegen seyn, gute Instrumente nach jedem Geschmacke und nach jedem Preise zu finden.' Johann Ferdinand Ritter von Schönfeld *Jahrbuch der Tonkunst von Wien und Prag 1796*, Vienna 1796 and facs. ed., München & Salzburg 1976, 90-1.

49 See Michael Latcham, 'The check in some early pianos and the development of piano technique around the turn of the 18th century', *Early Music*, XXI/1, February 1997, 28-42.

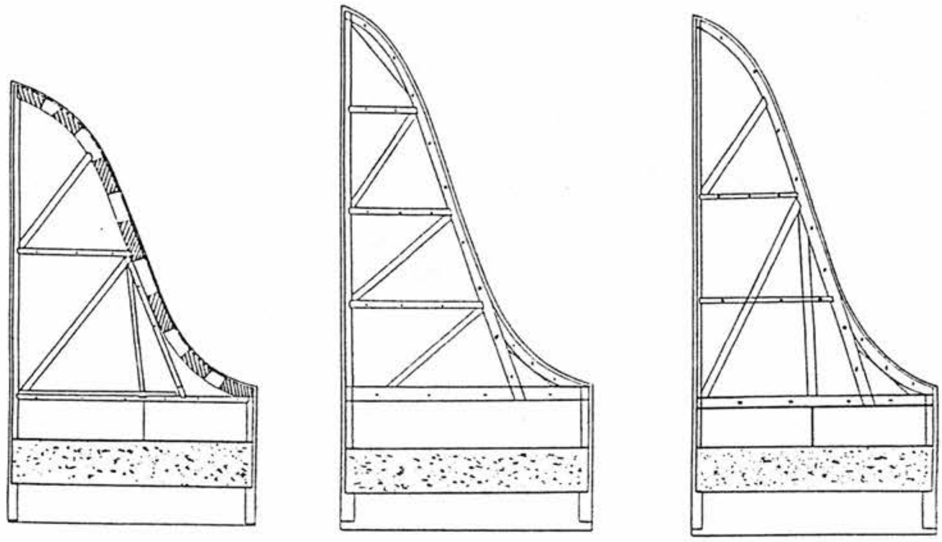
circumstances. But only the last two of Hofmann's pianos (H/c.1815 and H/c.1820) have fully fledged Viennese checks, like those in pianos by Walter, which operate no matter how hard the key is struck.[50] The earliest piano by Hofmann (H/c.1784a) has wooden *Kapseln*, in this respect again like Stein's pianos, but all the subsequent pianos have brass *Kapseln* like those in Walter's instruments.

Differences in internal construction

In the design of the internal structure the majority of the pianos by Stein differ from all but one of those pianos built by Walter before about 1800. The chief difference consists in the type of the main internal structural frame member which runs from the tail up towards the treble corner of the piano. In the two earliest surviving instruments by Stein this frame member is supported on blocks (in turn mounted on the baseboard) and runs in a continuous serpentine curve, following the bentside from the spine corner to the cheek. But, excepting the special case of the 1783 *vis-à-vis* piano-harpsichord, Stein's instruments dating from 1782 onwards have a different internal structure. The main internal frame member no longer follows the curve of the bentside but

50 Paul Poletti has pointed out to me however that the check does not operate at all during very fast repetition. The hammer does not even have time to reach the check before being activated again. This interesting observation makes the thesis that the check improves repetition untenable.

runs internally in a straight line from the tail to the bellyrail, intercepting the bellyrail at about a quarter its length from the cheek corner (ill. 10). This straight internal beam is not supported on blocks but extends the full height from under the soundboard down to the baseboard. The soundboard is glued to the beam from the tenor downwards but in the treble the beam is reduced in height, leaving the soundboard free above. The straight beam, the belly rail, the internal cheek and the internal spine together form a shape roughly corresponding to the letter A, hence the usual name given to this structure, the A-frame. Stein may have been the first to design pianos with the A-frame inner construction.

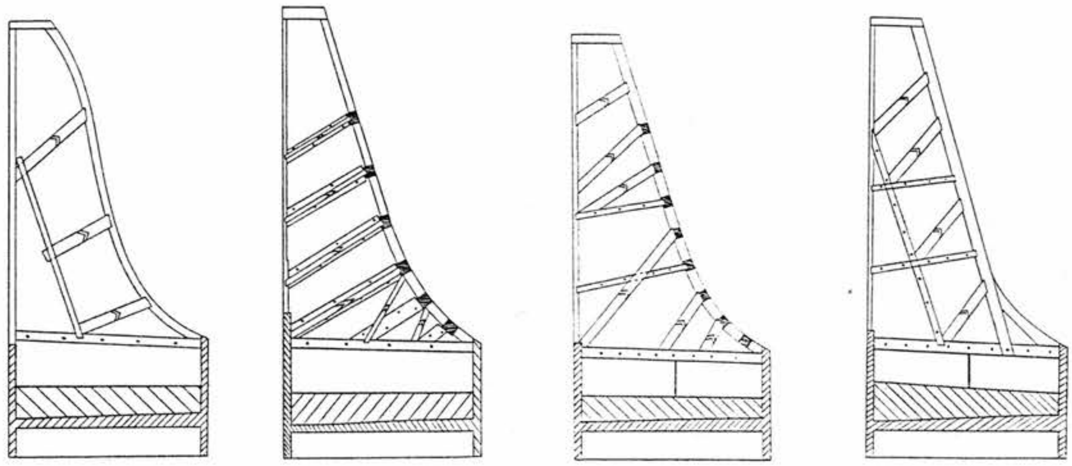


S/1781 S/1782 S/1788a

ill. 10 The different internal structures used by Stein. The gap spacer and the brace behind it in S/1781 (the piano of the *claviorganum*) are most probably later additions.

The wrestplanks are shaded and the bottom braces and the belly-rails marked with dots. The other braces are so-called flying buttresses. In the instrument of 1781 the continuously curving bentside liner is mounted on blocks which are in turn glued to the baseboard. These blocks are cross-hatched. S/1782 is the oldest dated piano with the so-called A-frame. Note the gap spacer in S/1788a. Stein began using the gap spacer in 1783.

The internal structure of Walter's earlier pianos includes a curved internal frame member, not the straight beam of the A-frame. In his four earliest pianos, those of about 1782, this internal frame member is very massive and for its complete length extends the full height from the underside of the soundboard, where it is about 35mm broad, down to the upper surface of the baseboard, where it is about 75mm broad. In the pianos made between about 1785 and 1800 Walter normally used a structure in which blocks mounted on the baseboard support a curved frame member. This structure is similar to that used by Stein before he began using the A-frame in 1782 (compare ill. 10 and ill. 11). In about 1800, Walter relinquished this structure in favour of Stein's A-frame, seventeen years after Stein had started to use it.



ill. 11 The different internal structures used by Walter.

The wrestplanks and their yokes are cross-hatched. The belly rails and bottom braces are marked with dots. The bottom braces in the c.1785 piano are glued flat on the baseboard. In the two later instruments they stand on the baseboard. The other braces, the so-called flying buttresses, are marked with arrows. In the instrument of c.1782 the continuously curving bentside liner is glued to the baseboard. The unmarked diagonal brace in the c.1782 piano acts as a soundboard liner and is only glued to the baseboard at the ends. In W/c.1785a and W/c.1800a the bentside liner is mounted on blocks which are morticed into the baseboard. These blocks are cross-hatched. Note the absence of a gap spacer in the two earlier pianos. In all the instruments the tail corner block and the outer walls have been omitted for the sake of clarity.

Two schools of piano building combined

As Von Schönfeld noted in 1796, both Stein and Walter had their followers. Some of these are documented as having worked for Stein or for Walter while others are now regarded as followers because their pianos show similarities to those of the two masters. Shortly after 1800 Walter's school had assumed the dominant position, at least with regard to the action and the soundboard layout. Nannette Streicher appears to have fought a rearguard action, championing her father's design against the more powerful instruments of the Walter school, but capitulating in 1805. By that date, it was Stein's design for the internal structure and Walter's design for the action and the soundboard which were almost universally used in the pianos of the Viennese and southern German traditions. From then on, the differences in piano design with respect to both the action and the structure are matters not so much of principle as of detail. Some important innovations were made to the soundboard design, notably the use of broad flat ribs instead of tall narrow ones. This change was probably introduced in the third decade of the nineteenth century by Conrad Graf.

A note on string length measurement correction

Owing to the distortion of old pianos, largely due to the string tension, the lengths of the strings are often shorter now than in the original design. The wrestplank, and with it the nut, is pulled in towards the bellyrail, tending to close the gap, situated between the wrestplank and the soundboard, through which the hammers rise to strike the strings. In all the pianos by Walter and in the pianos by Streicher made after about 1803 there is a strengthening rail, the so-called yoke, glued to the top front edge of the wrestplank. There is no such yoke in the pianos of Stein or in the earlier pianos of some of his followers, including those of Hofmann. The nameboards of Stein's pianos and all but the two six-octave pianos by Hofmann only serve a decorative function and can be taken out at will, in the same way as those of Italian harpsichords. In these pianos without the strengthening yoke the wrestplank is more liable to distortion. In some situations the wrestplank has split along the grain or has come away from the inner case sides to which it is joined. But usually the wrestplank is simply bent inwards. On some pianos of Hofmann, the wrestplank has been pulled forwards by 5mm or more in the tenor. The early pianos by Nannette Streicher, built when she was still working with her brother, also have no yoke. On one of these the wrestplank has distorted by 7mm, making a significant difference to the string lengths.[51]

51 S/c.1796/27.

The string lengths given here are the measured lengths from the nut pin to the bridge pin of the longer or longest string of a choir with the addition of the local extent of the forward movement of the wrestplank. This applies to those pianos measured by the author. When obtained from secondary sources in which no account is taken of wrestplank distortion the string lengths given are marked with an asterisk.

CHAPTER II

THE RANGE, THE NUMBER OF STRINGS FOR EACH CHOIR AND THE EXTENT OF BACK-PINNING

Range

It is generally true that from 1780 until at least 1820 the later the piano, the greater the range, reflecting the increase in ambitus exploited by composers. The widespread use of piano reductions of the work of the composers of the day, often in the form of the piano duet, also contributed to the increasingly greater range of the pianos made in the southern German and Viennese traditions from about 1800 onwards. In the domestic sphere, the piano reduction provided a means of access to music in much the same way as the recording does now.

The standard range for a grand piano of 1785 was five octaves, FF to f"'. Most grand pianos were double-strung throughout. By 1817 Christian Friedrich Gottlieb Thon could report that the standard range had increased to f"" and sometimes to seven octaves, from CC to c""':

> 'The range of a present-day grand piano consists usually of six full octaves from contra F in the bass to [the] octave of f"". Some, what is more, have 6 to 7 octaves and extend to c""'.'[52]

52 '[...] *und der Umfang eines heutigen Flügels beträgt meistens sechs volle*

The later pianos were generally triple-strung throughout, except for the extra notes in the bass, that is from CC to EE, when these were present.

Although it is generally true that the later the instrument, the greater the range, it is not true that an instrument with a greater range must be later than one with a smaller range. Jacob Adlung, for instance, mentions an instrument with the range CC to c"''' in 1758.[53] One piano of about 1810 by Joseph Brodmann has an exceptionally large range, from CC to f'''', and from CCC if the separate pedal instrument is included.[54] In about 1825 Brodmann built another piano of seven octaves, from CC to c"'''.[55] The Streicher firm made a piano with the unusual range FF to a'''' in 1827.[56] On this instrument one extra note is marked out on the nut in the bass showing that the wrestplank was probably originally intended for a range of seventy-eight notes, probably from CC to f'''' which was a standard range for the Streicher firm at the time, and adapted to the range FF to a'''', perhaps to accommodate the

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Octaven, nämlich von dem Contra F im Basse, bis zur Octave des viergestrichenen F; einige haben sogar $6^{1}/_{2}$ bis 7 Octaven und gehen bis in das fünfgestrichene C Octav.' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 89.

53 Jacob Adlung, *Anleitung zu der musikalischen Gelahrtheit*, Erfurt 1758, 556, footnote m.

54 {Vienna}.

55 {Switzerland}. Personal communication from Christopher Clarke, 1995.

56 S/1827/2185.

particular wishes of a client.

Even disregarding such exceptions, the pianos of the period cannot be dated from their ranges. Around 1800 builders offered instruments of varying compasses to suit the customer. In an article on Andreas and Nannette Streicher Wilhelm Lütge, discussing the correspondence between the Streichers and Härtel, the Leipzig publisher, states that

> '[...] the compass of the piano was determined by the client [...].'[57]

Lütge also mentions that in 1803 Härtel ordered

> '25 pianos of various sorts, with ranges of 5, $5^1/_2$ and 6 octaves.'[58]

In an 1805 price list, typical of the time, another Viennese builder, Joseph Wachtl, offered his pianos with the range FF to c"" as standard, although the customer could order extra keys at a cost of 4Fl. 30kr. a piece.[59]

The compass of the earliest of Walter's instruments is FF to

57 '[...] *der Umfang des Klaviers wurde von dem künstigen Besitzer bestimmt [...].*' Wilhelm Lütge, 'Andreas und Nannette Streicher', *Der Bär, Jahrbuch von Breitkopf und Härtel*, Leipzig 1927, 62.

58 Härtel ordered *'25 Claviere verschiedenster Art* [...], *und zwar in Umfang von 5, 5 1/2 und 6 Oktaven.*' Wilhelm Lütge, 'Andreas und Nannette Streicher', *Der Bär, Jahrbuch von Breitkopf und Härtel*, Leipzig 1927, 63.

59 *Clavier- Stimmbuch oder deutliche Anweizung wie jeder Musikfreund sein Clavier-Flügel, Forte-piano und Flügel-Fortepiano selbst stimmen, repariren, und bestmöglichst erhalen könne*, published by Gall, Vienna 1805,126.

f''' with the exception of W/c.1782e which extends to g'''. From about 1785 to 1800 some of his pianos have the latter compass and others go up to f'''.[60] Two pianos (W/c.1790 and W/c.1800c), both with the range FF to f''', have the positions marked (but neither drilled nor pinned) for tuning-pins for two more treble notes, suggesting that Walter's designs of the period were flexible and could accommodate small variations in range. After about 1800 the range was extended up to c'''' and in about 1815 to f'''', the standard of the day. Finally, there is one piano of about 1820 by the Walter firm with the range CC to f'''', later extended to g''''.

The range of Hofmann's surviving pianos never goes beyond FF in the bass but, with one exception, the later the piano the greater the range in the treble. The exception is H/c.1800 which extends only to g''' in the treble while two earlier pianos, H/c.1795g and H/c.1795h extend to c''''.

As range can only be taken as a rough guide to age, studies relating the compass used in the *oeuvre* of a composer to the instruments that composer intended for the interpretation of his work should be regarded with caution.[61] Conversely, dating an instrument on the basis of its range in relation to the compass required to play pieces by particular composers, even those working in the immediate circle of the builder of the instrument,

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60 W/c.1782a, b, c & d, W/c.1785a & b, W/c.1790, W/1796 and W/c.1800c all have a range from FF to f''' whereas W/c.1782e, W/c.1785c, W/c.1795 and W/c.1800a, b, d & e all extend up to g'''.

61 See for instance John Henry van der Meer, 'The keyboard string instruments at the disposal of Domenico Scarlatti', *The Galpin Society Journal*, L, March 1997, 136-179.

should be regarded as speculative.

Triple stringing

More and more power was required from the piano as the context in which it was used became less and less refined. This demand was largely met by increasing the thicknesses of the strings but also to some extent by increasing the extent of triple stringing and sometimes by cincluding a top section of quadruple stringing. In 1817 triple stringing was reported by Thon to be usual.

> 'Grand pianos are now practically universally strung with three unison strings for each note, at least in the upper octaves.'[62]

Triple stringing in the treble was also thought to provide a more even tone and a better resistance to the blows of the hammers. In his *Anleitung zu der musikalischen Gelahrtheit* of 1758, Jacob Adlung wrote:

> 'The most [*Hämmerwerke* or *Hämmerpantalone*] to be seen here are by Fickert of Zeiz, who supplies them with 5 strings in the upper octaves, 4 in the middle and 3 strings below, partly to maintain an even volume and partly, by the

62 '*Flügelinstrumente werden ietzt fast durchgängig mit drei übereinstimmenden Saiten auf einen Ton, wenigstens in den obern Octaven, bezogen* [...].' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 45.

plurality of the thin strings, to resist the heavy blows of the hammers more adequately.'[63]

The precise age of the undated pianos surveyed here cannot be judged from their range. Similarly, no hard and fast rules can be made about the relationship between triple stringing in the treble and the date of manufacture. Christoph Gottlieb Schröter, writing in 1764, gives a description of the piano he invented. For that date the piano had the unusually large range of FF to g''', double stringing from FF to c#, triple stringing from d to a#' and quadruple stringing from b' to g'''. He writes:

> 'If this appears to be too heavy take two strings from contra F to b for each choir and from c' to g''' three strings.'[64]

Triple stringing in the pianos of Walter and his followers

While Nannette Streicher generally double-strung her pianos throughout until as late as 1804, the pianos of Walter are all triple-

63 *'Die mehresten, welche hier zu sehen, hat Fickert in Zeiz verfertiget, welche sie pflegt in den obern Oktaven 5fach, mitten 4fach, unten aber 3fach zu beziehen, theils damit eine Gleichheit in der Stärke des Klanges erhalten werde, theils damit die klaren Saiten durch die Menge dem starken Schlage besser wiederstehen.'* Jacob Adlung, *Anleitung zu der musikalischen Gelahrtheit*, Erfurt 1758, 559.

64 Friedrich Wilhelm Marpurg, *Kritische Briefe über die Tonkunst*, III/1, Berlin 1764, 95. *'Wem diese Eintheilung der Chöre zu stark scheinet, der nehme vom Contra-F bis h zwey Saiten auf ein Chor. vom c' bis g3 drey Saiten.'*

strung in the treble from as early as 1785 onwards.[65] Those of his firm made between about 1790 and 1805 are triple-strung from $a^{\#}$' upwards while the six-octave pianos, of about 1810 onwards, are triple-strung throughout. The one six-and-a-half-octave instrument (originally CC to f""), of about 1820, is double-strung from CC to EE and triple-strung from FF to f"'.

The instruments of Johann Georg Gröber, who had probably been an apprentice or a journeyman at the workshop of Walter and who worked in Innsbruck between about 1800 and 1830, provide examples of intervening stages. Two of his pianos, probably made between 1800 and 1805, change from two to three strings at $a^{\#}$'.[66] His five subsequent surviving pianos, which probably date from between 1805 and 1815, change to triple stringing lower down at $d^{\#}$'.[67] One of about 1820 changes to triple stringing at c, and one of about 1830 at FF.[68]

The three surviving grand pianos by Jakob Pfister, who was certainly a journeyman at the Walter workshop are also triple-strung from $a^{\#}$'.[69] They date from c.1800 to c.1805. Nine pianos of c.1800 to c.1810 by Michael Rosenberger, another follower of

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65 The third string of each choir in the treble of Walter's earliest pianos, W/c.1782a & b, may have been added later. The layout of the tuning pins for these strings is different to that of the other two strings suggesting later re-working. Stein had already used triple stringing between 1781 and 1783.

66 {Austria 1} and {Austria 2}.

67 {New Haven}, {Nuremberg}, {England}, {Austria 3} and {Austria 4}.

68 {Austria 5} and {Innsbruck}.

69 {Munich}, {Würzburg} and {Nuremberg}. All three have the range FF-a"'.

Walter, change to triple stringing at b', a semitone higher than in Walter's pianos of the period, while the later ones of about 1825 are triple-strung throughout.[70] Caspar Catholnick, also a follower of Walter, changed to triple stringing at a' in one piano with the range FF-c"", but higher, at c", in another piano of the same range and in one of six octaves, FF-f"".[71]

Two pianos (F/1 and F/2) by another follower of Walter, Johann Fritz, are triple-strung from c" upwards. The next (F/3), chronologically speaking, changes to triple stringing three notes lower down at f#' and the next (F/4) is triple-strung throughout. These instruments are all of six octaves, FF to f"". Those by Fritz of six-and-a-half octaves (F/6 to F/8) also have triple stringing from FF upwards but are double-strung for each of the five extra notes CC to EE. The six-octave instruments probably date from between about 1810 and 1815 while the larger instruments probably date from between 1815 and 1825.

Triple stringing in the pianos of Stein and his followers

In Stein's *vis-à-vis* instrument of 1777 the piano is double-strung throughout. This is the earliest surviving instrument by Stein. The instruments belonging to the next chronological group, dating from

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70 Rosenberger: earlier pianos: {Germany 1}, {Goudhurst}, {Germany 2}, {Milan}, {Italy}, {Vienna 1} {Vienna 2}, {Bad Krozingen}, {Budapest}; later pianos: {Austria}, {Japan}, {Cremona}.

71 At a' in {Halle}, at c" in {England} and {U.S.A.}.

between 1781 and sometime in 1783, are triple-strung in the treble.[72] The piano of the *claviorganum* of 1781 has three strings for each note from a" to the top note f"' while the other pianos of this group are triple-strung from e" to f"'. In the last group, made between 1783 and1792, the Stein firm reverted to double stringing throughout the compass. There are three exceptions which are triple-strung in the treble, again from e" to f"'.

The majority of the followers of Stein working at the end of the eighteenth century and the beginning of the nineteenth century, including Senft, Schautz, Wirth, Lemme and Dulcken double-strung their pianos throughout the compass, as did Stein in his later pianos.[73] One piano by Schautz and those of Adam Achatius Schiedmayer and his younger brother Johann David Schiedmayer, however, change at a".[74] This change to triple stringing in the treble is not surprising in the pianos of Johann David Schiedmayer considering that he was a journeyman at the Stein workshop from 1778 to 1781, the period in which Stein also designed his pianos for triple stringing in the treble.

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72 See Michael Latcham, 'The Pianos of Johann Andreas Stein', *Studien zur Aufführungspraxis und Interpretation der Musik des 18. Jahrhunderts*, Michaelstein, November 1996, 15-49, for a detailed discussion of Stein's three phases.

73 Senft: {Nuremberg}, c.1795; Schautz: {Germany}, c.1800 and {Augsburg}, 1802; Wirth: {England}, c.1790 and {Munich}, 1803; Lemme: {New York}, c.1795; Dulcken: {The Hague}, 1793, {Sotheby}, c.1795, {Washington} c.1795, {Berlin}, c.1795 and {Germany}, c.1795.

74 Schautz: {Solothurn}, 1792; {A. A. Schiedmayer: {Nuremberg}, 1797; J. D. Schiedmayer: {Munich}, 1785, {Nuremberg}, 1794, {Erlangen}, c.1795, {Germany 1}, 1801 and {Germany 2}, 1783.

Triple stringing in the pianos of the Streicher firm

Until 1805 Nannette Streicher generally followed her father's later practice of double-stringing throughout the compass. In 1805 she changed this conservative attitude and is said to have made

> 'two sorts of *Fortepianos* , some with a strong sound and others with a weaker sound, according to the wishes of the individual. The former are strung in the treble with three strings and the latter with two.'[75]

The oldest surviving instrument by Streicher with triple stringing, starting at a#', was indeed made in 1805.[76] One piano by Streicher, of 1807, has triple stringing from D#, one of 1811 from C#, and one of 1816 from BB upwards. In general, the later the piano the lower down the triple stringing begins. By 1839, the pianos by Johann Baptiste Streicher usually have a range from CC to f'''' or g'''' and the triple stringing starts at EE. There is however no strict relationship between the age, the range and the changeover to triple stringing in the pianos of the Streicher firm, as shown in table 1.

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75 In 1805 Streicher began to build '*zweierlei Arten von Fortepianos* [...], *und zwar solche mit starkem und mit schwächerem Ton, je nach Wunsch der einzelnen; bei ersteren bezieht er den Diskant mit 3, bei letzteren mit zwei Saiten* [...].' Wilhelm Lütge, 'Andreas und Nannette Streicher', *Der Bär, Jahrbuch von Breitkopf und Härtel,* 1927, 64. Unfortunately, the 65 letters written by Andreas Streicher to G. Chr. Härtel between 1800 and 1807, from which Lütge gleaned much information, were lost during the second world war. Nonetheless, the precision of the observation that Streicher built instruments with two strings and others with three strings in the treble is such that it would have been a difficult for Lütge to have imagined it.

76 S/1805/649.

Pianos by Streicher
Range and the number of strings for each note

Code	Range	No. of notes	Bichord/Trichord transition	No. of trichord choirs
S/c.1796	FF-g'''	63	all bichord	none
S/c.1800	FF-g'''	63	all bichord	none
S/c.1804a & b	FF-c''''	68	all bichord	none
S/1805/649	FF-c''''	68	a'/a#'	27
S/1805/673	FF-c''''	68	a'/a#'	27
S/1807/733	CC-f''''	78	D/D#	64
S/1808/764	CC-f''''	78	BB/C	66
S/1811/902	FF-f''''	73	C/C#	65
S/1813/961	FF-f''''	73	C/C#	65
S/1814/1031	FF-f''''	73	AA#/BB	67
S/1814/1060	FF-f''''	73	AA#/BB	67
S/1816/1117	FF-f''''	73	AA#/BB	67
S/1819/1415	FF-f''''	73	AA#/BB	67
S/1819/1425	FF-f''''	73	AA#/BB	67
S/1820/1486	FF-f''''	73	AA#/BB	67
S/1820/1550	FF-f''''	73	AA#/BB	67
S/1823/1756	CC-f''''	78	DD#/EE	74
S/1827/2185	FF-a''''	77	all trichord	77
S/1828/2237	FF-f''''	73	all trichord	73
S/1830/2383	FF-f''''	73	AA/AA#	68
S/1832/2584	CC-f''''	78	DD#/EE	74
S/1839/3261	CC-f''''	78	DD#/EE	74
S/1839/3299	CC-g''''	80	EE/FF	75
S/1839/3304	CC-g''''	80	DD#/EE	76
S/1847/4032	AAA-a''''	85	C#/D	68
S/1858/5459	CC-a''''	82	DD#/EE	78

Table 1

Triple stringing in the pianos of Hofmann

In all of those instruments by Streicher and Walter with both a change from two to three strings and string gauge markings a gauge change to a thinner size is marked where the triple stringing begins, as one might expect. This is not the case with Hofmann. He appears to have avoided a gauge change at the changeover from two to three strings. Except in the two six-octave pianos, which are triple-strung throughout, all his pianos, whether they have a range from FF to f''', g''' or c'''', are double-strung to b' and triple-strung from c'' to the top.

Back-pinning

In both harpsichords and pianos it is essential that the strings make good contact with both the bridge and the nut so that the energy of the vibrating string is not dissipated at either end of the sounding part of the string. It is also essential that this energy is efficiently transmitted to the soundboard through the bridge pins and the bridge itself. In harpsichords the contact with the nut pin and the bridge pin is partly achieved by angling the string sideways, through about 5°, as it passes both these pins. The resulting side-bearing is usually supplemented by down-bearing. The strings leave the tuning pins at a height below the level of the crown of the nut and finally arrive at the hitch-pin rail at a height lower than the crown of the bridge. The necessary contact with the nut and the bridge is thus achieved through side-bearing and down-bearing.

In the bass, however, where the strings are thickest and the soundboard often at its thinnest, the down-bearing could cause excessive sinking of the soundboard. It is also in the bass, where the strings run at a small angle in relation to the direction of the bridge, that the side-bearing would tend both to make the bridge roll over towards the bentside and to tear the bridge from the soundboard. In the treble there is little danger of the bridge rolling because the direction of the bridge in relation to that of the strings approaches a right-angle. There is also little danger of the soundboard sinking in the treble because there is relatively little down-bearing from the thinner strings.

Probably in order to avoid the problems in the bass, the lower strings of many eighteenth-century harpsichords are back-pinned rather than angled. Back-pins are inserted behind the bridge pins such that the strings pass to the left of the bridge pins and to the right of the back-pins. Beyond the back-pin, each string runs on to its hitch-pin in the same direction as from the nut pin to the bridge pin, that is, with no side-bearing. In some French harpsichords the back-pinning in the bass is probably intended to serve an additional function. In conjunction with a raised hitch-pin rail, the back-pinning eliminates the downward pressure on the bridge entirely and thus prevents the soundboard from sinking.

Back-pinning also appears to have been used to prevent the same problems occurring in pianos although the use of the raised hitch-pin rail is only found in pianos not discussed here.[77] But an up-striking hammer action brings with it an additional problem: the blows of the hammers tend to lift the strings from the bridge and from the nut, especially in the treble. Adlung writes

> '[...] when the hammers strike the strings from below, these must be fastened to the bridge by something so that they cannot rise up.'[78]

Back-pinning at the nut

A very few late eighteenth-century pianos have back-pinning at the nut, probably also to counter the blows of the hammers. One early piano by Walter has back-pinning at the nut from A to a'.[79] Another, by Stein's pupil Schmidt, has back-pinning at the nut from d# " to the top note f"'.[80] Back-pinning on the nut in the tenor is standard in the pianos by the Streicher firm made in the second half of the nineteenth century. In the pianos surveyed here, however, back-pinning is usually only found at the bridge.

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77 Notably in the early nineteenth-century pianos of Robert Stodart.

78 '*Wenn die Hämmer die Saiten von unten her berühren, so müssen diese durch etwas auf dem Stege befestiget werden, daß sie nicht aufsteigen können.*' Jacob Adlung, *Anleitung zu der musikalischen Gelahrtheit*, Erfurt 1758,559-60.

79 W/1782a. W/1782b (Mozart's piano) may originally have also had a back-pinned nut. The present nut is a later replacement. The 16' strings of Stein's *vis-à-vis* instrument in Verona are also back-pinned at the nut.

80 {Nuremberg 1}, 1789.

The 'inverted' wrestplank[81]

The problem of the strings lifting from the nut was sometimes solved by using a so-called 'inverted' wrestplank, for instance in the piano of the *vis-à-vis* instrument by Stein in Verona. The tuning-pins only protrude a little above the wrestplank, to enable tuning, and go through the wrestplank, emerging underneath where the strings are wound to them (ill. 9). The nut is glued to the underside of the wrestplank. The 'inverted' wrestplank is found in pianos by Bartolomeo Cristofori and by both Gottfried and Johann Heinrich Silbermann. Stein worked in the Silbermann workshop in Strasbourg from 1748 to 1749 and it was probably there that he learnt of the principle of the 'inverted' wrestplank. The 'inverted' wrestplank ensures that the blow of the hammer contributes to the contact between the string and the nut. The down-striking action patented by J. B. Streicher in 1823 serves a similar function. Because the strings are struck from above with the nut and wrestplank in their normal configuration, the hammers beat the strings into both the nut and the bridge, thus solving the problem of lifting strings both at the nut and the bridge. This same advantageous down-striking action is found in the vertical grand piano claimed as the invention of Jakob Bleyer in 1811.

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81 Stewart Pollens was the first to coin the term 'inverted wrestplank' in his article 'The pianos of Bartolomeo Cristofori', *Journal of the American Musical Instrument Society*, X, 1984, 36-68.

Back-pinning at the bridge

As in the harpsichord, the back-pinning of the bass strings on the bridge in the piano serves as an alternative to side-bearing. Back-pinning in the treble, on the other hand, was probably intended to counteract the tendency of the hammers to lift the strings from the bridge. But on the whole the pianos of the late eighteenth century discussed here have no treble back-pinning, reflecting the lighter playing techniques used then in comparison to those of the early nineteenth century.[82] Only by about 1815 is it a general rule that back-pinning was used throughout the compass. By then, the heavier techniques employed would almost certainly have required back-pinning in the treble to keep the strings properly seated on the bridge.

In the absence of treble back-pinning the strings are angled back towards the cheek through between 5° and 14°, depending on the builder, thus providing side-bearing. The bridge in the treble is generally about 3mm higher than the hitch-pin rail, providing down-bearing. In addition, the bridge pins are not vertical but angled towards the spine, thus trapping the strings securely on the bridge. Similarly, angled nut pins hold the strings to the nut.

Where there is back-pinning, the strings first pass the bridge pins, which also lean to the left (towards the spine) and

82 Cristofori already back-pinned his double-strung pianos throughout in 1720. English grand pianos of the late eighteenth century are generally triple-strung and back-pinned throughout, for instance the earliest known grand piano by John Broadwood (1787, No. 69), privately owned in England.

then the back-pins, which lean to the right. In the pianos discussed here, the hole for the back-pin of each string is drilled directly behind the bridge pin, in the same line as the direction of the sounding part of the string. The string passes to the left of the bridge pin and to the right of the back-pin and then usually continues straight back to the hitch-pin rail. In some instances the strings are not only back-pinned but also angled.[83]

Back-pinning in the pianos of Stein, Streicher and the followers of Stein

Generally, the extent of back-pinning is not directly related either to the changeover to triple stringing or to the range of the instrument. This is shown in table 2 for instruments by Stein and by Streicher.

83 For instance in W/1796 and K/6.

Pianos by Stein and Streicher
Range, back-pinning and triple stringing

Code	Range	No. of Notes	Back-pinning	No. of back-pinned notes	Bichord/ Trichord transition
S/1777	FF-f'''	61	FF-f'''	61	all bichord
S/1781	FF-f'''	61	FF-g'	39	g#''/a''
S/1782	FF-f'''	61	FF-f#'	38	d#''/e''
S/1783a	FF-f'''	61	FF-b'	43	d#''/e''
S/1783b	FF-f'''	61	FF-b'	43	d#''/e''
S/1783c	FF-f'''	61	FF-d#''	47	d#''/e''
S/1783d	FF-f'''	61	FF-b'	43	all trichord
S/1783e	FF-f'''	61	FF-b'	43	all bichord
S/1784	FF-f'''	61	FF-b'	43	d#''/e''
S/1785	FF-f'''	61	FF-f'''	61	d#''/e''
S/1786	FF-f'''	61	FF-f'''	61	all bichord
S/1788a	FF-f'''	61	FF-f'''	61	all bichord
S/1788b	FF-f'''	61	FF-f'''	61	all bichord
S/1790	FF-f'''	61	FF-b'	43	all bichord
S/1792	FF-f'''	61	FF-f'''*	61*	d#''/e''
S/1793	FF-f'''	61	FF-b'	43	all bichord
S/c.1796/27	FF-g'''	63	FF-b'	43	all bichord
S/1800	FF-g'''	63	FF-b'	43	all bichord
S/c.1804a	FF-c''''	68	FF-b'	43	all bichord
S/c.1804b	FF-c''''	68	FF-b'	43	all bichord
S/1805/649	FF-c''''	68	FF-c''''	68	a'/a#'
S/1805/673	FF-c''''	68	FF-c''''	68	a'/a#'
S/1807/733	CC-f''''	78	CC-f''''	78	D/D#
S/1808/764	CC-f''''	78	CC-f''''	78	BB/C
S/1811/902	FF-f''''	73	FF-f''''	73	C/C#
S/1813/961	FF-f''''	73	FF-f''''	73	C/C#
S/1814/1031	FF-f''''	73	FF-f''''	73	AA#/BB
S/1814/1060	FF-f''''	73	FF-f''''	73	AA#/BB
S/1816/1117	FF-f''''	73	FF-f''''	73	AA#/BB
S/1819/1415	FF-f''''	73	FF-f''''	73	AA#/BB
S/1819/1425	FF-f''''	73	FF-f''''	73	AA#/BB
S/1820/1486	FF-f''''	73	FF-f''''	73	AA#/BB
S/1823/1756	CC-f''''	78	CC-f''''	78	DD#/EE
S/1827/2185	FF-a''''	77	FF-a''''	77	all trichord
S/1828/2237	FF-f''''	73	FF-f''''	73	all trichord
S/1830/2383	FF-f''''	73	FF-f''''	73	AA/AA#

Table 2

*Note: in S/1792, the strings are angled as well as back-pinned from c'' to f''' suggesting that the back-pinning originally extended only as far as b'.

The decision of 1790 made in the Stein workshop to change from back-pinning their pianos throughout and reverting to angling the strings in the treble may be related to the fact that owing to her father's illness, Nannette had already assumed responsibility for the firm's production by that date. She may have chosen to adopt her father's earlier policy of not back-pinning in the treble, a policy he had relinquished in 1784. Only in 1805 did Nannette resume back-pinning throughout the compass.

Turning to the followers of Stein, their pianos show considerable variation with regard to back-pinning. One piano by the Gräbner brothers of 1791, for instance, is back-pinned to a#' while those of 1793 and 1794 are back-pinned one note higher to b', as are the two earliest surviving instruments by Johann David Schiedmayer (1783 and 1785).[84] Those which are back-pinned throughout include the later pianos of Johann David Schiedmayer (1794, c.1795 and 1801), the one surviving piano by his brother Adam Achatius Schiedmayer (1797), the eighteenth-century pianos by J. L. Dulcken and pianos by J. Schmidt (1789 and 1803).[85] The general tendency which emerges is that the later the piano, the higher the back-pinning. The many exceptions, however, show that no fixed rule can be made, certainly when comparing the

84 Schiedmayer: {Germany 2}, 1783, {Munich}, 1785; Gräbner: {Italy}, 1791, {Nuremberg}, 1793, {U.S.A}, 1793, {Halle}, 1794.

85 J. D. Schiedmayer: {Nuremberg}, 1794, {Erlangen}, c.1795, {Germany 1}, 1801; A.A. Schiedmayer: {Nuremberg}, 1797; Dulcken: {The Hague}, 1793, {Sotheby}, c.1795, {Washington}, c.1795 and {Germany}, c.1795; Schmidt: {Nuremberg 1}, 1789, {Salzburg 1}, 1794, {Washington}, c.1795, {Nuremberg 2}, c.1795, {Nuremberg 3}, c.1795, {New York}, c.1795, {Salzburg 2}, 1803.

instruments of two different builders. For instance, a piano by Schautz of 1792 is back-pinned to f#" while a piano by F. J. Wirth of eleven years later, 1803, is back-pinned only as far as the note b.[86] Both these builders worked in Augsburg and both are recorded as pupils of Stein.

The dated pianos of Stein and his followers show a general tendency in which the later the piano the greater the range, the more the triple stringing and the greater the extent of back-pinning. This is shown in table 3. Notwithstanding this tendency however it should be emphasised that none of these variables can be used to date particular pianos, either within the work of Stein and his followers taken as a single school or indeed within the work of each individual builder. The same generally applies to the pianos of Hofmann, Walter and their followers.

86 Schautz: {Solothurn}; Wirth: {Munich}.

Dated pianos by Stein and his followers
Range, triple stringing and back-pinning

Maker	Code	Date	Range	No. of notes	Bichord/ Trichord transition	Back-pinning	No. of back-pinned notes
J.A. Stein	S/1781	1781	FF-f'''	61	g#"/a"	FF-g'	39
J.A. Stein	S/1783	1783	FF-f'''	61	d#"/e"	FF-b'	43
J. Schiedmayer	{Germany 2}	1783	FF-f'''	61	g#"/a"	FF-b'	43
J. Schiedmayer	{Munich}	1785	FF-f'''	61	g#"/a"	FF-b'	43
J.A. Stein	S/1788a	1788	FF-f'''	61	all 2	FF-f'''	all
J. Schmidt	{Nuremberg1}	1789	FF-f'''	61	all 2	FF-f'''	all
Gebr. Gräbner	{Italy}	1791	FF-f'''	61	all 2	FF-a#'	43
M. Schautz	{Solothurn}	1792	FF-f'''	61	g#"/a"	FF-f#"	50
Gebr. Gräbner	{Nuremberg}	1793	FF-f'''	61	all 2	FF-b'	43
Gebr. Gräbner	{U.S.A.}	1793	FF-f'''	61	all 2	FF-b'	43
J. L. Dulcken	{The Hague}	1793	FF-f'''	61	all 2	FF-f'''	all
Gebr. Gräbner	{Halle}	1794	FF-f'''	61	all 2	FF-b'	43
J. Schmidt	{Salzburg1}	1794	FF-f'''	61	all 2	FF-f'''	all
J. Schiedmayer	{Nuremberg}	1794	FF-f'''	61	g#"/a"	FF-f'''	all
A. Schiedmayer	{Nuremberg}	1797	FF-f'''	61	g#"/a"	FF-f'''	all
K. Lemme	{New York}	1797	FF-f'''	61	all 2	FF-a'	42
Geschw. Stein	S/1800	1800	FF-g'''	63	all 2	FF-b'	43
J. Schiedmayer	{Germany 1}	1801	FF-f'''	61	g#"/a"	FF-f'''	all
M. Schautz	{Augsburg}	1802	FF-f'''	61	all 2	FF-g#"	52
F.J. Wirth	{Munich}	1803	FF-f'''	61	all 2	FF-b	31
J. Schmidt	{Salzburg2}	1803	FF-f'''	61	all 2	FF-f'''	all
N. Streicher	S/1805/649	1805	FF-c''''	68	a/a#'	FF-c''''	all
N. Streicher	S/1807/733	1807	CC-f''''	78	D/D#	CC-f''''	all
N. Streicher	S/1811/902	1811	FF-f''''	73	C/C#	FF-f''''	all
N. Streicher	S/1816/1117	1816	FF-f''''	73	AA#/BB	FF-f''''	all
N. Streicher	S/1819/1425	1819	FF-f''''	73	AA#/BB	FF-f''''	all
N. Streicher	S/1823/1756	1823	CC-f''''	78	DD#/EE	CC-f''''	all
N. Streicher	S/1827/2185	1827	FF-a''''	77	all 3	FF-a''''	all
N. Streicher	S/1828/2237	1828	FF-f''''	73	all 3	FF-f''''	all
N. Streicher	S/1830/2383	1830	FF-f''''	73	AA/AA#	FF-f''''	all

Table 3

Back-pinning in the pianos of Hofmann and his followers

In the pianos of Hofmann no relationship can be observed between the extent of back-pinning and the change from two to three strings. The same appears to be true for the pianos by his followers. Of two pianos by Karl Benedickt, for instance, one is triple-strung from c" and back-pinned throughout while the other is back-pinned for the double-strung section of the compass, that is up to b', but not in the triple-strung section from c" to g"'.[87] Probably the earliest piano by another follower of Hofmann, Joseph Brodmann, has triple stringing from c" and back-pinning up to g#" while another slightly later piano by the same maker has triple stringing from a#' upwards and back-pinning throughout.[88] The date or estimated date, the range, the changeover from two to three strings and the extent of back-pinning are given for the pianos of Hofmann and some of those of his followers in table 4.

87 {Ptui}, c.1795 and {U.S.A.}, c.1795, both FF-g"'.

88 {Austria}, c.1795 (FF-f"') and {Halle}, c.1800 (FF-g"').

Pianos by Hofmann and his followers
Range, triple stringing
and back-pinning

Maker	Code	Date	Range	No. of notes	Bichord/ Trichord transition	Back-pinning	No. of back-pinned notes
F. Hofmann	H/c.1784a	c.1784	FF-f'''	61	b'/c''	FF-a''	53
F. Hofmann	H/c.1784b	c.1784	FF-f'''	61	b'/c''	FF-b''	55
F. Hofmann	H/c.1785a	c.1785	FF-f'''	61	b'/c''	FF-c'''	53
F. Hofmann	H/c.1785b	c.1785	FF-f'''	61	b'/c''	FF-b''	53
F. Hofmann	H/c.1785c	c.1785	FF-f'''	61	b'/c''	FF-b''	53
F. Hofmann	H/c.1785d	c.1785	FF-f'''	61	b'/c''	FF-f'''	all
F. Hofmann	H/c.1790a	c.1790	FF-f'''	61	b'/c''	FF-f'''	all
F. Hofmann	H/c.1790b	c.1790	FF-f'''	61	b'/c''	FF-f'''	all
F. Hofmann	H/c.1795a	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795b	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795c	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795d	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795e	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795f	c.1795	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1795g	c.1795	FF-c''''	68	b'/c''	FF-c''''	all
F. Hofmann	H/c.1795h	c.1795	FF-c''''	68	b'/c''	FF-c''''	all
K. Benedickt	{U.S.A.}	c.1795	FF-g'''	63	b'/c''	FF-b'	41
K. Benedickt	{Ptui}	c.1795	FF-g'''	63	b'/c''	FF-f'''	all
J. Brodmann	{Austria}	c.1795	FF-g'''	63	b'/c''	FF-g#''	50
J. Brodmann	{Halle}	c.1800	FF-g'''	63	a'/a#'	FF-g'''	all
F. Hofmann	H/c.1800	c.1800	FF-g'''	63	b'/c''	FF-g'''	all
F. Hofmann	H/c.1805	c.1805	FF-c''''	68	b'/c''	FF-c''''	all
J. Brodmann	{Vienna}	c.1810	CC-f''''	78	C#/D	CC-f''''	all
J. Brodmann	{Paris}	1814	FF-f''''	73	all 3	FF-f''''	all
F. Hofmann	H/c.1815	c.1815	FF-f''''	73	all 3	FF-f''''	all
J. Brodmann	{Wörlitz}	1818	CC-f''''	78	GG/GG#	CC-f''''	all
F. Hofmann	H/c.1820	c.1820	FF-f''''	73	all 3	FF-f''''	all
J. Brodmann	{Netherlands2}	c.1825	CC-g''''	80	EE/FF	CC-g''''	all

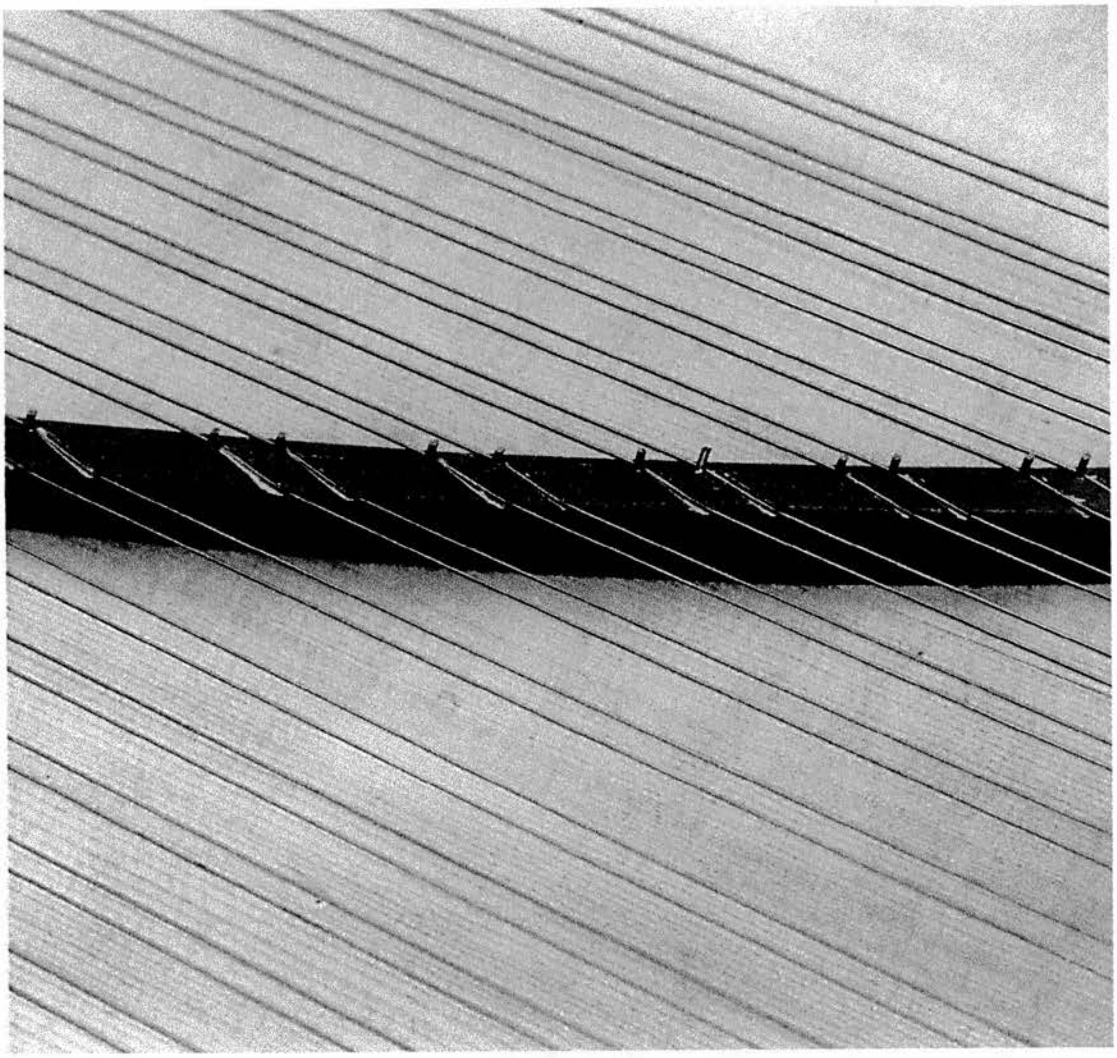
Table 4

Back-pinning in the pianos of Walter and his followers

Walter's earliest pianos have no back-pinning. Instead there are slits cut in the bridge behind the bridge pins. These slits serve the function of back-pins (ill. 12). Such slits are mentioned at the end of a long essay on the improvement of keyboard instruments written by a certain 'J. B. v. H.' and published in Carl Friedrich Cramer's *Magazin der Musik* in 1784:

> 'According to the old way, the strings are guided by wire hooks fixed in the bridge such that the strings do not exert their full pressure on the soundboard but to the side, so that they hardly, if at all, touch the bridge. Like this the soundboard will hardly, if at all, be noticeably brought into vibration, and it can occur that some of them are not even firmly held by the wire, so that, what is more, the already bad sound becomes unbearable through the extraneous noise. It would thus be better if one guided the strings on the bridge in small groves and, by giving the bridge an adequate height, allowed part of the tension to be exerted on the soundboard.'[89]

89 '*Nach der alten Art füht man die Saiten um dräthene Häckchen, so auf den Stege bevestiget sind, dergestalt herum, das solche ihren ganzen Druck nicht gegen den Resonanzboden, sonder nach der Seite zu haben, indem sie fast gar nicht auf dem Stege ruhn. In diesem Fall wird die Resonanzboden von den Saiten wenig oder gar nicht merklich erschüttert; und trift ist es sich, daß einige derselben auch nicht einmal vest am Drath liegen, so wird ohnehin schon schlechte Ton durch einen unangenehmen Nebengesang völlig unerträglich. Man würde also besser thun, wenn man die Saiten auf dem Stege in kleinen Kerben ruhen und durch eine hinlängliche Höhe desselben einen Theil ihrer Spannkraft gegen den Resonanzboden wirken liesse.*' J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet.' *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 298.



ill. 12 Slits instead of back-pins in the bridge of W/1785a

The author of this *Magazin der Musik* essay, who earlier in the article shows himself to be a theoretician with little or no practical experience as a builder of keyboard instruments, had probably seen such slits in clavichords from northern Germany, perhaps in an instrument by the then famous Johann Augustin Straube of Berlin.[90]

In Walter's earliest pianos these slits are not found in the treble. Instead, the strings there are angled beyond the bridge pins. In W/1782a & b there are slits up to f#", in W/1782d up to g#', in W/1782e up to g', and in W/c.1785a, W/c.1785c and in W/c.1790 up to a'. W/c.1795 is curious because there are neither slits nor back-pins and only the top, triple-strung section of the compass has the strings angled back as they leave the bridge pins, by 7°. The soundboard has been removed and re-installed, however, which must have entailed removing the hitch-pin rail so that the relationship between the bridge pins and the hitch-pins may have been disturbed. From W/1796 onwards all the pianos of the Walter firm have back-pinning at the bridge except in the treble where the strings are angled. The back-pinning, range and triple stringing of the surviving pianos of the Walter firm are summarized in table 5.

The pianos by Walter's follower Rosenberger also demonstrate the lack of coherence between date, range, back-pinning and the change to triple stringing. The approximate dates,

90 The two clavichords by Straube, one in the Haags Gemeentemuseum, The Hague and one in the Musik-Instrumenten Museum, Leipzig have slits in the bridge.

range, changeover to triple stringing and the extent of back-pinning for pianos by Pfister, Rosenberger, Catholnick and Fritz, all followers of Walter, are given in table 6.

Pianos by Walter
Range, triple stringing and back-pinning

Code	Range	No. of notes	Back-pinning	No. of back-pinned notes	Bichord/ Trichord transition
W/c.1782a	FF-f'''	61	slits FF-f#''	slits 50	g#'/a'
W/c.1782b	FF-f'''	61	slits FF-f#''	slits 50	g#'/a'
W/c.1782d	FF-f'''	61	slits FF-g#'	slits 40	g#'/a'
W/c.1782e	FF-g'''	63	slits FF-g'	slits 39	a'/a#'
W/c.1785a	FF-f'''	61	slits FF-a'	slits 41	a'/a#'
W/c.1785c	FF-g'''	63	slits FF-a'	slits 41	a'/a#'
W/c.1790	FF-f'''	61	slits FF-a'	slits 41	a'/a#'
W/c.1795	FF-f'''	61	none	none	a'/a#'
W/1796	FF-f'''	61	FF-a'	41	a'/a#'
W/c.1800a	FF-g'''	63	FF-a'	41	a'/a#'
W/c.1800b	FF-g'''	63	FF-a'	41	a'/a#'
W/c.1800c	FF-f'''	61	FF-a'	41	a'/a#'
W/c.1800d	FF-g'''	63	FF-a'	41	a'/a#'
W/c.1800e	FF-g'''	63	FF-a'	41	a'/a#'
W/c.1805a	FF-c''''	68	FF-c''''	68	a'/a#'
W/c.1815a	FF-f''''	73	FF-c'''	56	all trichord
W/c.1815b	FF-f''''	73	FF-g'''	63	all trichord
W/c.1815c	FF-f''''	73	FF-f'	49	all trichord
W/c.1815d	FF-f''''	73	FF-f''''	73	all trichord
W/c.1815e	FF-f''''	73	FF-f''''	73	all trichord
W/c.1815f	FF-f''''	73	FF-f'	49	all trichord
W/c.1815g	FF-f''''	73	FF-f''''	73	all trichord
W/c.1817	FF-f''''	73	FF-d'''	58	all trichord
W/c.1820	CC-f''''*	80	FF-f''''	unknown	EE/FF

Table 5

* This is the original compass. The instrument was later extended to g''''.

Pianos by followers of Walter
Range, triple stringing and back-pinning

Maker	Code	Date	Range	No. of notes	Bichord/ Trichord transition	Back-pinning	No. of back-pinned notes
J. Pfister	{Munich}	c.1800	FF-a'''	65	a'/a#'	FF-a'''	all
J. Pfister	{Würzburg}	c.1805	FF-a'''	65	a'/a#'	FF-a'''	all
J. Pfister	{Nuremberg}	c.1805	FF-a'''	65	a'/a#'	FF-a'''	all
M. Rosenberger	{Germany 1}	c.1800	FF-g'''	63	a#'/b'	FF-g#''	52
M. Rosenberger	{Vienna 2}	c.1805	FF-g'''	63	a#'/b'	FF-a#''	54
M. Rosenberger	{Germany 2}	c.1805	FF-c''''	68	a#'/b'	FF-c'''	all
M. Rosenberger	{Goudhurst}	c.1805	FF-c''''	68	a#'/b'	FF-c'''	all
M. Rosenberger	{Milan}	c.1805	FF-f''''	73	a#'/b'	FF-f''''	all
M. Rosenberger	{Italy}	c.1805	FF-f''''	73	a#'/b'	FF-f''''	all
M. Rosenberger	{Vienna 1}	c.1805	FF-f''''	73	a#'/b'	FF-f''''	all
M. Rosenberger	{B. Krozingen}	c.1810	FF-f''''	73	a#'/b'	FF-g'''	63
M. Rosenberger	{Budapest}	c.1810	FF-f''''	73	a#'/b'	FF-g'''	63
J. Fritz	F/1	c.1810	FF-f''''	73	b'/c''	FF-f''''	all
J. Fritz	F/2	c.1815	FF-f''''	73	b'/c''	FF-f''''	all
J. Fritz	F/3	c.1815	FF-f''''	73	f'/f#'	FF-f''''	all
J. Fritz	F/3a	1813	FF-f''''	73	f'/f#'	FF-f''''	all
J. Fritz	F/4	c.1815	FF-f''''	73	all 3	FF-f''''	all
C. Catholnik	{Halle}	c.1815	FF-c''''	68	g#'/a'	FF-c''''	all
C. Catholnik	{England}	c.1815	FF-c''''	68	b'/c''	FF-c''''	all
C. Catholnik	{U.S.A.}	c.1815	FF-f''''	73	b'/c''	FF-f''''	all
J. Fritz	F/6	c.1820	CC-f''''	78	EE/FF	CC-f''''	all
J. Fritz	F/7	c.1820	CC-g''''	80	EE/FF	CC-g''''	all
J. Fritz	F/8	c.1825	CC-g''''	80	EE/FF	CC-g''''	all
M. Rosenberger	{Austria}	c.1825	FF-f''''	73	all 3	FF-f''''	all
M. Rosenberger	{Japan}	c.1825	FF-f''''	73	all 3	FF-f''''	all
M. Rosenberger	{Cremona}	c.1825	FF-f''''	73	all 3	FF-f''''	all

Table 6

Range, triple stringing and back-pinning in the pianos of Könnicke and Schantz

The two 1796 pianos by Könnicke and another similar but undated instrument by the same maker, all with the range FF to g''', change to triple stringing at a#' and are not back-pinned from the same note upwards.[91] Another instrument by Könnicke, however, of the same range, approximately the same date and which also changes to triple stringing at a#' is back-pinned throughout the compass.[92] The two surviving six-octave instruments by Könnicke, both made in about 1810, also change to triple stringing at b' but are back-pinned as far as g#''.[93]

The first seven of the surviving grand pianos by Schantz are all triple-strung from b' up to the top of the compass and the extent of their back-pinning varies more or less consistently with range. Table 7 summarises the back-pinning, range and change from two to three strings for instruments by Könnicke and Schantz.

91 K/3, K/4 and K/1.

92 K/2.

93 K/6 and K/7.

Pianos by Könnicke and Schantz
Range, triple stringing and back-pinning

Maker	Code	Date	Range	No. of notes	Bichord/ trichord transition	Back-pinning	No. of back-pinned notes
J. Könnicke	K/1	c.1795	FF-g'''	63	a'/a#'	FF-a'	41
J. Könnicke	K/2	c.1795	FF-g'''	63	a'/a#'	FF-g'''	all
J. Könnicke	K/3	1796	FF-g'''	63	a'/a#'	FF-a'	41
J. Könnicke	K/4	1796	FF-g'''	63	a'/a#'	FF-a'	41
J. Könnicke	K/6	c.1810	FF-f''''	73	a'/a#'	FF-g#''	52
J. Könnicke	K/7	c.1810	FF-f''''	73	a'/a#'	FF-g#''	52
J. Schantz	Sz/2	c.1790	FF-g'''	63	a#'/b'	FF-a#'	42
J. Schantz	Sz/3	c.1795	FF-g'''	63	a#'/b'	FF-a#'	42
J. Schantz	Sz/4	c.1795	FF-a'''	65	a#'/b'	FF-a''	53
J. Schantz	Sz/4a	c.1795	FF-c''''	68	a#'/b'	FF-a''	53
J. Schantz	Sz/5	c.1795	FF-a'''	65	a#'/b'	FF-a''	53
J. Schantz	Sz/6	c.1795	FF-c''''	68	a#'/b'	FF-c'''	56
J. Schantz	Sz/7	c.1805	FF-f''''	73	a#'/b'	FF-f'''	61
J. Schantz	Sz/9	c.1810	FF-f''''	73	a#'/b'	FF-f'''	61
J. Schantz	Sz/9a	c.1810	FF-f''''	73	a#'/b'	FF-f'''	61
J. Schantz	Sz/10a	c.1815	FF-f''''	73	E/F	FF-f''''	all
J. Schantz	Sz/11	c.1815	FF-f''''	73	E/F	FF-f''''	all
J. Schantz	Sz/12a	c.1820	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/13	c.1820	FF-f''''	73	A#/B	FF-f''''	all
J. Schantz	Sz/14	c.1820	CC-f''''	78	EE/FF	CC-f''''	all
J. Schantz	Sz/14a	c.1820	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/15	c.1820	CC-f''''	78	all 3	CC-f''''	all
J. Schantz	Sz/12	1821	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/16a	c.1825	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/18	c.1825	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/19	c.1820	CC-f''''	78	all 3	CC-f''''	all
J. Schantz	Sz/20	c.1825	FF-f''''	73	all 3	FF-f''''	all
J. Schantz	Sz/22	c.1825	FF-g''''	75	all 3	FF-g''''	all

Table 7

Summary

A greater compass, more strings for each choir and back-pinning taken higher in the compass can all be seen as improvements to the piano. The advantages of a greater compass are obvious. More strings and back-pinning allow a heavier touch and thus the production of more volume. But the inconsistencies in the progress of these improvements show that the makers of the day were not always and not only taken up by the demand for ever larger and more powerful pianos. Of the builders surveyed here, Nannette Streicher was perhaps the most old-fashioned, at least until 1805. In comparison to Walter, she not only maintained a conservative attitude to action design but also to triple stringing and back-pinning, catering for a lighter touch. But in 1805 she began to change the design of her pianos and by 1807 was producing some of the largest and probably most powerful pianos in Vienna. Hofmann appears to have changed his design a little later, perhaps in 1810, shortly before he obtained the court title in 1812, although too few of his pianos from this transitional period survive to give an accurate picture. Walter's pianos of around 1800 show that he probably led the field at that time, with respect not only to action design, but also to back-pinning and triple stringing.

The differences in design between the different schools had largely disappeared by about 1810 when pianos of six or six-and-a-half octaves, back-pinned throughout the compass and triple-strung from FF to f"" had become standard.

CHAPTER III

STRING GAUGES AND STRING GAUGE SYSTEMS

The demand for more volume determined much of the development of the piano in the period around 1800. In general, piano builders responded in the design of their pianos by increasing the dimensions of such parts as the hammers and the bridge, by increasing the stiffness of the soundboard and, above all, by constantly increasing the diameter of the strings. In 1817 Thon wrote:

> With respect to thicknesses, the stringing - generally speaking - should be neither too thin nor too thick. In the first case the strings do not achieve the required effect. In the second case the tone is certainly round and full, but alas the strings are also very prone to breaking.[94]

Thon appears to imply that the thicker the strings the better and that only the fact that thicker strings break more easily restricts the use of heavier stringing.

The string gauge markings on the instruments were almost

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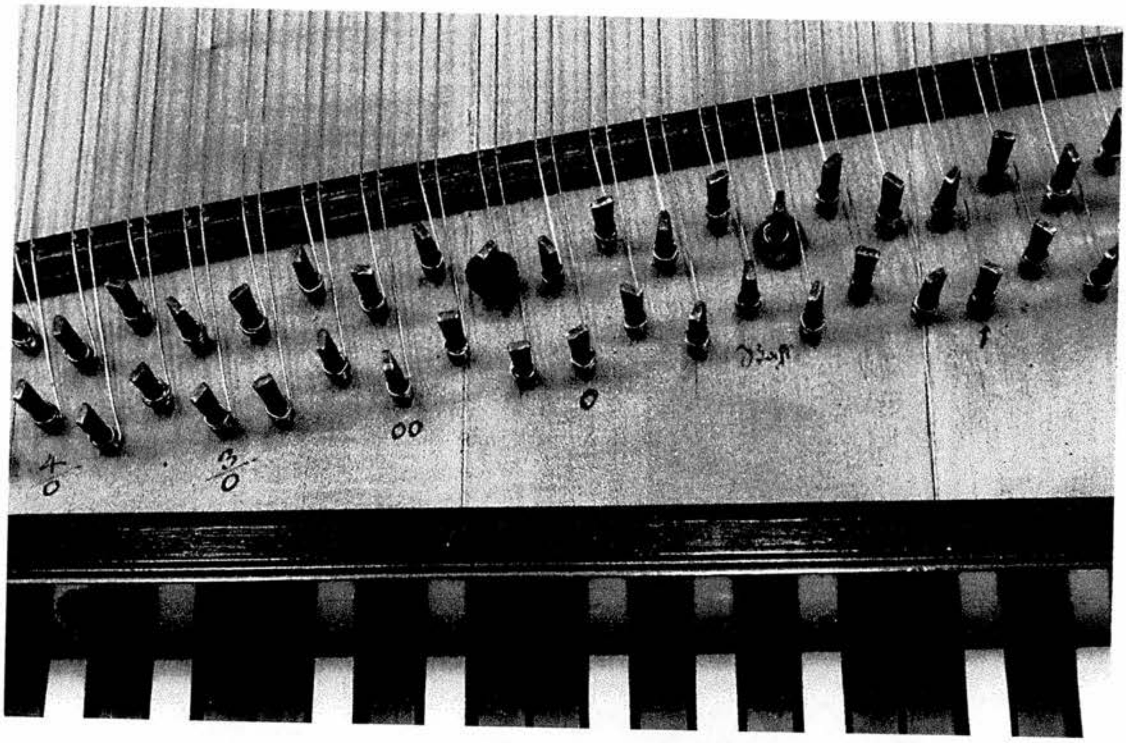
94 *'In Ansehung der Stärke, darf der Bezug - generell genommen - weder zu schwach noch zu stark seyn; im ersteren Fall leisten die Saiten nicht die erforderliche Wirkung; im zweiten ist der Ton zwar sehr rund und voll, aber leider! sind die Saiten dem Zerspringen auch sehr ausgesetzt.'* Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente,* Sondershausen 1817, 47.

certainly intended to indicate which gauges were to be used when replacing strings although alternatively, the gauge markings may have been used as a guide when the instrument was originally strung. A discussion of these string gauges, the string diameters to which they refer and the systems to which they belong is essential to an analysis of the development of the piano from the more delicate, lightly-strung instruments of before the French Revolution towards the later, more powerful and heavily-strung instruments of the romantic era.



ill. 13 String gauges marked on the wrestplank of a piano by Johann David Schiedmayer, 1785 ({Munich}). The word *Stahl*, indicating the start of iron strings can be seen at the note a.

Gauge markings

The different materials and thicknesses intended for the strings of a piano by its maker are often, but not always, indicated by string gauge markings found stamped or written on the wrestplank, the front edge of the soundboard or on the bridge (ill. 13). On the pianos discussed here the gauge markings which have survived are such that a gauge with a lower number is thicker than one with a higher number. Gauge 2, for instance, is thicker than gauge 3. Gauges thicker than gauge 1 are indicated by a number of zeros: gauge 0 or 1/0 is the next gauge thicker after gauge 1, gauge 00 or 2/0 is the next thicker after gauge 1/0 and so on.[95] A typical series of gauge markings for the Viennese and southern German pianos of the late eighteenth century start in the bass with gauge 7/0 as the thickest gauge and run up to gauge 4 in the treble as follows:

7/0, 6/0, 5/0, 4/0, 3/0, 2/0, 1/0, 1, 2, 3, 4

As a rule, each gauge mark denotes the diameter of the string next to which or under which it is written or stamped and for the subsequent higher strings until the next gauge mark is reached. In a few rare cases each gauge mark is repeated to indicate both the start and the finish of each size of wire, for instance in most of the

95 To avoid confusion I have not used forms such as 00 or 0 but always 2/0 and 1/0. As a gauge marking, 1/0 is only rarely found, for instance in the pianos of Brodmann, 0 being more usual. Nonetheless, for the sake of consistency I have used 1/0 instead of the usual 0 and 1/0½ instead of 0½.

surviving instruments by Gröber.

Another unusual use of gauge markings is shown by two other pianos by Gröber in which the gauge markings are not repeated but in which there is a gauge marking for the top note of the piano and none for the bottom note. For these two pianos Gröber appears to have marked the gauges beginning at the treble, rather than the bass. The gauge marking 3/0 at the note A, for instance, thus means that gauge 3/0 should be used at A and down to the note E which in turn is marked for the next gauge thicker, 4/0.[96]

The thinnest gauge used for the pianos discussed here is gauge 6, found on a piano by the Gräbner brothers of 1791 and on an instrument by Johann David Schiedmayer of 1785, while the thickest is gauge 12/0 on, for instance, S/1837/2991.[97]

In some cases there are no gauges marked in the bass. It may be that the gauge markings which are lacking have not survived or that the builder chose to indicate only some of the gauges, perhaps those of strings which were considered most likely to need replacement. The latter seems to be the case in a number

96 In {Austria 2} all the gauges are marked in this way, in {New Haven} only some.

97 One piano by J. D. Schiedmayer piano, {Erlangen}, has the gauge $5^{1}/_{2}$ marked at d#''', an anonymous instrument (probably South German) in the Colt Collection (Cat. No. 20, Inv. No. G267SV, attributed there to Stein or Schiedmayer but in the author's opinion by neither) has gauge 6, also marked at d#'''. The piano by the Gräbner brothers, {Italy}, has gauge 6 marked at d''' and the piano by Schiedmayer of 1785 {Munich} has gauge 6 marked at a''. Except for these, no pianos built in the southern German or Viennese traditions are known to the author with gauge markings for sizes thinner than gauge 5.

of the later pianos by Walter's firm. These have no gauges markings for the lowest octave.[98]

Half gauges

A development of the gauge system used was the introduction of intermediate or half-gauge sizes, making the increments between the gauges smaller. The most usual markings for these intermediate sizes found on surviving pianos are a little confusing. Gauge 5/0 is thicker than gauge 4/0 but the gauge between, thinner than 5/0 but thicker than 4/0, is marked $5/0^{1}/_{2}$, not $4/0^{1}/_{2}$. Similarly, gauge $2^{1}/_{2}$ is thinner than gauge 2 but thicker than gauge gauge 3. In order of decreasing thickness examples of these gauges are:

... 3/0, $3/0^{1}/_{2}$, 2/0, $2/0^{1}/_{2}$, 1/0, $1/0^{1}/_{2}$, 1, $1^{1}/_{2}$, 2, $2^{1}/_{2}$, 3...

Gauge markings and the string materials used

Usually, the repeat of a particular gauge mark indicates a change in string material, either from red brass to yellow brass or from brass to iron. The latter change in material is also sometimes indicated

98 W/c.1805a begins with gauge 3/0 at E, W/1815a, b and c begin with 3/0 at F, W/1815d with 4/0 at D.

by the word *weiß*, or white, referring to the colour of the iron compared to the yellow of the preceding brass, or by the word *Stahl*, steel. Changes of material are often not indicated, however. Two instruments by Walter, for instance, both with complete sets of gauge markings (W/1796 and W/c.1815f) have no repeated gauge markings although they must originally have been strung in brass and iron. Again, although W/c.1805a has no repeated gauge markings there are old strings, presumed original, of red brass, yellow brass and iron still in place.[99] The absence of repeated gauge markings obviously does not mean that there were no changeovers. There was certainly always an actual change from brass to iron, and although the changeover from red brass to yellow brass is only rarely indicated, red brass is still present in the extreme bass in a number of instances where no changeover is specified by the repeat of a gauge marking.[100]

Covered strings

Gauge markings are sometimes lacking in the bass, for instance in many of the pianos by the Walter firm built in about 1815. This was perhaps because the makers did not expect strings to break in

99 W/c.1805a has red brass strings for FF and FF$^{\#}$ (diameter 0.90mm), GG$^{\#}$ and AA (0.80mm), and yellow brass for BB (0.80mm), C and C$^{\#}$ (0.73mm).

100 Two instruments by Joseph Brodmann, {Vienna} and {Italy}, and two by Walter, W/c.1800b and W/c.1800e have repeated gauge marks indicating red brass.

the bass, thus making the gauge markings superfluous. In the extreme bass of grand pianos built after about 1830 there are also often no gauge markings, but for a different reason. In such later pianos the lack of gauge markings in the bass is an indication of covered strings, that is, strings made up of a core wire onto which a covering of thinner wire has been wound. The materials of the core and the covering vary but iron covered with brass is common.

In the grand pianos of before 1820 the scaling in the bass is only rarely short enough to merit the use of covered strings. Stein, however, on page 284 of his notebook, gives a stringing list including covered strings for a *'Forte Piano petit'*.[101] This piano may have been a small grand piano. The stringing list begins with the words:

FF bis C überspon

meaning that the strings for the notes from FF to C are to be over-spun or covered. Because surviving square pianos and harp-shaped pianos often do have covered strings in the bass, one might suppose that the *Forte Piano petit* was just such an instrument. But there are also short grand pianos of the late eighteenth century with string lengths in the bass suited to covered strings. There is also evidence suggesting that the bass strings were indeed covered. The piano of the 1781 *claviorganum* by Stein is a case in point,

101 The author is grateful to Dr. and Frau Wolfgang Streicher for permission to publish information from Stein's notebook.

being substantially shorter (about 300mm) than his other pianos. The length of the string for FF is only 1468mm in the *claviorganum* while it is 1713mm in a piano by Stein made one year later in 1782. Furthermore, in the *claviorganum* indentations in the crown of the bridge where it is crossed by the strings of the lowest five notes show that this instrument once had covered strings. A number of the shorter *Tangentenflügel* of Christoph Friedrich Schmahl also have bass scalings suited to covered strings. One of these, of 1791, still retains covered strings in the bass (iron covered with brass) and other *Tangentenflügel* by Schmahl have indentations in the bridge similar to those in the piano of the *claviorganum* by Stein.[102] The *petit* instrument with *überspon* strings mentioned on page 284 of the notebook could thus refer to such a short grand piano rather than to a harp-shaped or square piano.

Later, in the 1830's, builders started using covered strings for the lowest notes as a matter of course. One piano by Brodmann of about 1825 has a relatively long string length for CC (1879mm), and gauge markings for covered strings for the first five notes starting with

3./ 4/0

102 The instrument by Schmahl is {The Hague}. See Michael Latcham, 'The sound of some late eighteenth-century keyboard instruments'. *Jaarboek, Haags Gemeentemuseum*, III, 1993, 30-41. Other short instruments by Schmahl which probably originally had covered strings are {Leipzig} and {Nuremberg}. In these instruments only the right-hand string of each choir was covered. The left-hand string was of iron and tuned to 4' pitch.

at CC, meaning a core of gauge 4/0 and a covering of gauge 3.[103]

But the use of covered strings in the 1820's is exceptional. In this respect the pianos of the Streicher firm are more typical. The oldest instrument by Streicher with covered strings known to the author was made in 1839 and has a string length of 1892mm for the note CC. Because the gauge markings do not begin until the note FF, it can be concluded that covered strings were intended for the lowest five notes, CC to EE.[104] Another piano, this time with a down-striking action but built in the same year (about five months later) has a longer CC string, at 1965mm, and no covered strings. The marking at CC is for gauge 12/0.[105] It can be assumed that these pianos by Streicher with short bass scalings have covered strings to compensate for the shorter string lengths, as in the modern piano. Later, from sometime in the 1840's, the use of covered strings in the bass became standard for the Streicher firm.

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103 The piano by Brodmann of c. 1825 is {France} and the other by him of 1818 is {Wörlitz}.

104 S/1839/3261. Another instrument of the same type (S/1839/3338) also lacks the same gauge markings for the same notes in the bass. In both these instances there are old covered strings still in place so it is most unlikely that these are cases in which the gauge markings are missing.

105 S/1839/3304. This is a down-striking instrument. Others by Streicher of the same type and period also have non-covered strings in the bass (S/1832/2548, S/1835/2750, S/1837/2991) and start with gauge 12/0 for CC.

The production of music wire in the eighteenth and early nineteenth centuries

To understand the various systems of gauges into which the wire appears to have been sorted it is first necessary to turn to the subject of wire drawing.

One of the key tenets of traditional wire drawing, extensively discussed by Remy Gug in his article '*En remontant la filière de Thoiry à Nuremberg*', is that each successive diameter of wire produced during the drawing process was literally gauged by measuring the resultant increase in length, rather than by measuring the diameter as we would today with a micrometer.[106] A measuring tool, the *Zängelmaß*, marked out with a small number of units of length was used. After inserting the beginning of the wire into the die, a number of units, for instance four, were marked off on the length of string yet to pass through the die. After drawing, the drawer would check that the four units had become, for instance, five.[107] With each successive draw the length increased according to a fixed proportion. The reduction in diameter thus also followed a geometric progression.

In practice however, the dies used for drawing the wire became worn very fast, with appreciable enlargement occurring

106 Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 4-76. See especially p. 22.

107 Attention to the use of the drawing ratio of 4 : 5 was first mentioned by William R. Thomas and J. J. K. Rhodes in 'Harpsichords and the art of wire-drawing', *The Organ Yearbook*, X, 1979, 126-39.

even during a single draw; the diameter of a length of wire could be thicker at the end than at the beginning. There was however no need to observe any strict accuracy and the iron and brass wire was probably produced in a continuum of diameters ranging from the thickest to the thinnest required. These would have been sorted into gauges subsequently.

One practical method of sorting the wire into gauges was to use plates in which a series of slits were cut or in which a series of holes were drilled.[108] The slits or holes ranged from small to large and each was marked for a particular gauge, presumably conforming to some gauge system. If the wire passed through a particular slit or hole, say the one marked 2/0, but was too thick to pass through the next, marked 1/0, the wire would be designated 2/0. In this way all wire ranging in diameter between the size of the slit or hole marked 2/0 and just thicker than the size of the slit or hole marked 1/0 would be sorted, and sold to the piano maker, as gauge 2/0. Within each gauge there is thus a possible range of diameters equivalent to the difference in diameter between two consecutive gauges. This range might have been even greater for the following reason. Dies could easily become worn such that the wire produced was oval in cross-section. When measuring such wire using a measuring plate with slits it could be that the short

108 See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 91-105. Wire gauges are illustrated on page 105. See also Karl Karmarsch, *Jahrbücher des Kaiserlichen königlichen polytechnischen Institutes in Wien,* 13 Band, Wien 1828, p.170-1 for descriptions of measuring plates employing slits and holes. I am most grateful to Alfons Huber for bringing this source to my attention.

axis just passed into the particular slit marked 2/0. Measured according to its long axis such wire would have been sorted as 3/0.

Because the measurement of the decrease in the diameter of wire during the drawing process is historically based in the measurement of the factor by which wire increases in length when drawn it is not surprising to find a pervading idea in the history of string gauges that the diameters of the gauges within a system should follow a geometric progression. By contrast, wire today is usually accurately drawn to diameters to follow an arithmetic progression, that is, the diameters of a series of gauges decrease by a fixed amount rather than by a constant factor. In the late eighteenth and early nineteenth century, although the wire was probably not very accurately drawn, the principle lying behind the systems into which the wire was sorted was the geometric progression.

It is possible that wire gauge systems were originally defined by the diameters of wire specially drawn for calibrating the sizes of the slits or holes in the measuring plates. We can imagine the following train of events. Master wire drawers used the *Zängelmaß* in a consistent and accurate manner to ensure the same proportional increase in length with each successive draw. Wear on the dies would have had to have been checked at the beginning and the end of each draw. Each successive draw was assigned to the next gauge number thinner. The series of gauges produced thus followed a constant drawing ratio and the successive diameters of the series of gauges accurately followed a geometric progression. This series of diameters was then used to calibrate the widths of the slits or holes in the measuring plates, filing the slits or reaming the holes to size. Like the wire, the resultant series of slits or holes would thus also have followed a geometric progression.

But there are various reasons for rejecting this hypothetical train of events as a reflection of what actually happened. First, Friedemann Hellwig measured the widths of the slits in a number of measuring plates (not specifically intended for music wire) dating from the seventeenth and eighteenth centuries and found that the widths did not decrease according to a geometric progression.[109] But second, and more interestingly, Gug has argued that the wire drawers did not select each diameter they produced to form a series of gauges; not every successive draw was assigned a new gauge number.[110] Sometimes wire was drawn down twice to achieve a new gauge, sometimes three times.[111] Gug also shows that during the process of drawing a single series of gauges the *Zängelmaß* was not always used consistently. In drawing a single series of gauges the drawer might sometimes have used a proportional increase in length in the ratio 4 : 5 to arrive at some gauges but other ratios to arrive at other gauges.[112]

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109 See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 97-100.

110 See Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 45.

111 See Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 56-7.

112 See Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 28.

Inasmuch as gauge systems follow a geometric progression they probably do so not because of a method of drawing wire but because they were sorted into systems construed using the principle of the geometric progression. This is the case for some systems of the early nineteenth century and may have been the case in the eighteenth century. Knowing the diameters of the thickest and thinnest strings required and the number of gauges between them the diameters of the intervening gauges could be calculated using the geometric progression as an *a priori* principle.

It is thus not unreasonable to assume that sorting systems were based on the principle of the geometric progression and thus that in practice the diameters of the gauges of any system will also approximate a geometric progression. This presents a method of identifying and comparing different gauge systems according to their gauge ratios, that is, the ratio between successive diameters when fitted to a straight line. By subjecting a set of known or measured string diameters of a particular string gauge system to a regression analysis the gauge ratio of that system can be defined and the diameters of each gauge fitted to that ratio can be calculated. This gauge ratio, together with the fitted diameter of just one gauge can then be taken as the defining characteristics of the gauge system.

The evidence for different gauge systems used in the southern German and Viennese traditions is derived from the presumed original strings found on historical instruments and from written sources. Before turning to this evidence the subject of the originality of strings must therefore be discussed and some general problems relating to string gauge systems outlined.

Old strings or original strings?

The usual criteria used for judging the originality of old strings are:

1) the string loops at the hitch-pins and the string coils on the wrest pins are neatly and consistently made;

2) the old strings change diameter at the string gauge markings;

3) at least some of the wire is oval in cross-section due to the wear on the dies used for drawing.

These may be necessary criteria for judging the originality of old wire but they are not sufficient.[113] Instruments, then as now, were re-strung. Sometimes this might have entailed just a few strings but at other times all the strings would have been replaced. The later, possibly thicker strings of a complete re-stringing may still conform to all the criteria on the list.

The strings on one piano by Walter, W/c.1800d, present an

113 These criteria are described in Grant O'Brien, 'Stringing Materials and Gauges for Clavichords by I. C. Gerlach and H. A. and J. A. Hass', *De Clavicordio, Proceedings of the International Clavichord Symposium*, Magnano 1993, 128-9. O'Brien adds a last criterion for the originality of strings, that as a whole a gauge system should have a drawing ratio close to 5/4. I would reject this criterion. Other drawing ratios were used and there is no certainty that the geometric progression was always the basis of gauge systems.

example of the difficulties involved. A large number of the strings on this instrument conform to the listed criteria. Alfons Huber has therefore assumed that these strings were those used by Walter when the instrument was first made.[114] But there is little doubt that this piano has a later, if old, soundboard. If this is the case the present strings are most unlikely to be those of Walter.[115] They are more likely to be new strings put on the instrument after glueing in the later soundboard. These strings merely suggest that the soundboard was replaced at a time when the Nuremberg system was still in use, that is, before about 1820.

It was not uncommon to replace soundboards in the early nineteenth century. J. H. C. Nachersberg wrote in 1804

> 'If the bridge has become unglued from the soundboard, there is nothing to be done but to put in a new soundboard and, if the old bridge is still usable, one glues it on again.'[116]

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114 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 199 and 212.

115 See Michael Latcham, 'Soundboards Old & New', *Galpin Society Journal*, XLV, 1992, 50-8.

116 '*Hat sich der Steg vom Resonanzboden entfernt, so bleibt kein Weg übrig, als dieser, daß man einen neuen Resonanzboden einziehe und den alten Steg, wenn er sonst noch brauchbar ist, wieder darauf leimen.*' J. H. C. Nachersberg, *Stimmbuch, oder vielmehr: Anweisung, wie jeder Liebhaber sein Clavierinstrument, sey es übrigens ein Saiten- oder ein Pfeifenwerk, selbst repariren und also auch stimmen könne*, 2nd revised edition, Breslau and Leipzig 1804, 150. This passage also occurs in *Clavier- Stimmbuch oder deutliche Anweizung wie jeder Musikfreund sein Clavier-Flügel, Forte-piano und Flügel-Fortepiano selbst stimmen, repariren, und bestmöglichst erhalen könne*, published by Gall, Vienna 1805, 98. It could be possible that the publisher of Nachersberg's book in Vienna (without acknowledgement) was Franz Josef Gall, the phrenologist and friend of Nannette Streicher.

Jakob Bleyer, in his text on his vertical pianos of 1811, states that

> 'If one builds a case in the normal fashion, that is with solid [inner] case sides, however strongly one braces these sides one finds that after a half year, when one tears out the soundboard, all the braces are loose having become pressed into the case sides by a line [a little more than 2mm] because of the tension of the strings which is about 90 *Centner* [4500kg].'[117]

Instruments were repaired then as now and sometimes this will have required a new soundboard and hence new strings.

Most early pianos will probably have been completely re-strung, simply as a matter of course, perhaps even on numerous occasions. In his handbook of 1817 Thon gives a list of the type of repairs for which one requires an instrument builder. These include replacing the wrestplank, making a new action, a new soundboard, re-glueing the entire hitch-pin rail and putting on

> '... a complete new set of thicker strings.'[118]

117 '*Baut man einen Kasten auf die gewöhnliche Art, nämlich mit massieven Sargstücken und verstrebt die Wände noch so sehr, so findet man in einem halben Jahre, wenn man den Resonanzboden heraus reisst, dass sich durch die Spannung der Saiten, welche bey 90 Centner beträgt, alle Streben bey einer Linie tief in den Wänden eingedrükt haben, und nun ganz los sind.*' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII*, Leipzig, November 1811, 75.

118 '[...] *ein durchaus neuer und stärkerer Saitenbezug* [...].' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 97.

In their handbook of 1824 on the piano Johann Lorenz Schiedmayer and Carl Dieudonné remark that:

> 'One can assume that a set of strings will be past service after a period of ten years and that then a piano owner who wants to restore youth to his instrument will do well to have the instrument newly strung. If he can, he should have this operation undertaken by an able instrument maker or by a tuner well versed in this matter. The result will always be a more powerful and rounder tone.'[119]

It is thus unlikely that more than a few pianos of before 1800 with original strings exist.

General problems relating to the interpretation of string gauge markings

Two important principles involved in the interpretation of string gauge markings are worth special attention. The first of these is

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119 '*Man kann annehmen, daß eine Besaitung nach einem Zeitraume von zehn Jahren* ausgedient *hat, und daß dann ein Clavierbesitzer, der gerne sein Instrument verjüngen möchte, wohl thun wird, dasselbe neu besaiten zu lassen, wenn er Gelegenheit hat, diese Geschäft durch einen geschickten Instrumentenmacher oder einen der Sache ganz gewachsenen Stimmer vornehmen zu lassen. Der Erfolg wird immer ein kräftiger und runderer Ton seyn.*' Johann Lorenz Schiedmayer and Carl Dieudonné, *Kurze Anleitung zu einer richtigen Kentniss und Behandlung der Forte-Pianos in Beziehung auf das Spielen, Stimmen und Erhalten derselben, besonders derer, welche in der Werkstätte von Dieudonné und Schiedmayer in Stuttgart verfertigt werden*, Stuttgart 1824, facs. Tübingen 1994, 73-4. Stewart Pollens drew my attention to this source in his article 'Early Nineteenth-Century German-Language Works on Piano Maintenance: A Review of Published Information Concerning the Stringing, Tuning, and Adjustment of the Fortepiano', *Early Keyboard Journal*, IIX, 1990, 91-109.

that the origin of the wire does not necessarily indicate that the wire was sorted into a gauge system associated with that origin. Nuremberg wire was not always sorted into the Nuremberg gauge system and wire sorted according to the Nuremberg system did not always originate in Nuremberg.

The second principle is that the presence or absence of half gauge markings is not sufficient to distinguish the gauge system to which the gauge markings refer. For instance, a lack of half gauges does not necessarily indicate the Nuremberg system and the presence of half gauges does not exclude that system. As a corollary to this one can add that two sets of gauge markings which ostensibly appear to refer to different gauge systems can in fact refer to the same gauge system; two different sets of gauge markings can refer to the same set of diameters. In such a case the gauge ratios would be the same but the gauge markings would differ such that, for instance, gauges 8/0, 7/0 and 6/0 in one system could refer to the same diameters as gauges 8/0, 8/0$^1/_2$ and 7/0 in another. The two systems are the same, only the names of the gauges are different.

The Nuremberg gauge system

i) Nuremberg wire and the Nuremberg system

As Alfons Huber, Remy Gug and others have shown, the wire used by most of the piano builders working in the southern German and

Austrian traditions until at least 1800 came from Nuremberg and the system of gauges into which the wire was usually sorted is today referred to as the Nuremberg gauge system.[120]

ii) The Nuremberg system and half gauges

Half or intermediate gauges were only rarely included in the Nuremberg system before 1800. Stein's notebook, already mentioned above, contains several stringing lists for clavichords, harpsichords and pianos. A stringing scheme for a '*forte piano*', given on page 270 under the heading '*Neuer Bezug FP*' (New stringing F[orte]P[iano]), contains half gauges in the treble:

FF	GG	AA# *stahl*	C	D#	F#
5/O	4/O	3/O	OO	O	1
c	g	d'	g'	c''	f''
2	3	4	5	*halb*	6
a''	c'''________				
halb	7				

120 The reader is referred to the work of Remy Gug and Alfons Huber for discussions and descriptions of the Nuremberg wire production and gauge system. See Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 4-76 and Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 193-222.

Although it is not completely certain that these gauges refer to the Nuremberg system it is unlikely that Stein, working before 1800, would have used any other. It might be objected that it is unusual to find a stringing scheme for a piano using gauges 6 and 7 and thus that these thin gauges could be taken to indicate some as yet unrecognized alternative gauge system to the Nuremberg system. There is, however, one other mention of both gauges 6 and 7 for a piano in Nachersberg's *Stimmbuch* of 1804.[121] There, gauges 6 and 7 are used for two instruments, both called '*Fortepiano*' [piano], in contrast to a '*Mozartschen Flügelfortepiano*' [Mozartian grand piano] which has gauge 6 for the last notes up to g'''. In his handbook of 1817, Thon also contrasts the '*Fortepiano*' or '*Pianoforte*', the square piano, with the '*Flügelfortepiano*' or '*Flügel*', the grand piano.[122] In the eighteenth century the square pianos and harp-shaped instruments were more lightly strung in the treble than the contemporary grand pianos. It thus seems likely that the '*F*[orte]*P*[iano]' with half gauges mentioned in Stein's

121 J. H. C. Nachersberg, *Stimmbuch, oder vielmehr: Anweisung, wie jeder Liebhaber sein Clavierinstrument, sey es übrigens ein Saiten- oder ein Pfeifenwerk, selbst repariren und also auch stimmen könne*, 2nd revised edition, Breslau and Leipzig 1804, 124-6.

122 Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 2. Thon distinguishes:

1) Das	*Klavier, Klavichord* [Clavichord];
2) -	*Fortepiano oder Pianoforte* [Square piano];
3) -	*Flügelfortepiano, gemeinhin Flügel* [Grand piano];
4) -	*Claveçin oder Clavecimbalon, sonst Flügel* [Harpsichord];
5) -	*Spinett* [Spinet]

notebook was a square piano or perhaps a harp-shaped instrument and thus required thinner gauges than those normally used for grand pianos.

None of the surviving grand pianos by Stein has half gauge markings. On the other hand, some pianos by other makers working in the period during which the Nuremberg system is reported to have been generally used have a few sporadic half gauge markings. A piano by J. D. Schiedmayer of about 1795, for instance, has one half gauge, $5^1/_2$ marked at d#'''.[123] A piano by Rosenberger of about 1810 has the following series of gauges marked: 8/0, 7/0, 6/0, 5/0, 4/0, 3/0, 2/0, $2/0^1/_2$, 1/0, $1/0^1/_2$, 1, $1^1/_2$, 2, 3, 4.[124] A few pianos built around 1815 also have only one or two half gauges marked. An upright grand piano by Joseph Wachtl made in Vienna between 1812 and 1818, for instance, has gauge $2^1/_2$ marked at c'''' while all the other gauges are whole number sizes.[125] One piano by Johann Schantz (Sz/10, c.1815) has two half gauges marked ($3/0^1/_2$ and $2/0^1/_2$) and three pianos by Streicher (S/1811/902, S/1816/1117 and S/1819/1415) have one half gauge marked (gauge $1/0^1/_2$). Such sporadic half gauge markings certainly do not necessarily point to the use of a new system and are more likely to indicate a refinement of the Nuremberg system.

123 {Erlangen}.

124 {Bad Krozingen}.

125 Technisches Museum, Vienna, Inv. No. 15 280. Details of this instrument were kindly supplied by Sabine Klaus from her forthcoming catalogue of the instruments in the Technisches Museum.

In 1811 Jakob Bleyer indirectly mentions the use of half gauges for Nuremberg wire when he compares the strings used in Vienna with those of Nuremberg:

> 'Today's strings, like those of Nuremberg, only have 6 gauges between a and b, and if one admits half gauges, one only has 15 gauges of which the half sizes give rise to error.'[126]

Friedemann Hellwig quotes Karl Karmarsch who, in 1833, makes mention of a sorting system for Nuremberg wire including half gauges.

> 'The Nuremberg strings famed for their excellent quality exist in 13 sorts which are marked by numbers in the following way: $9/0^1/_2$ [*Hellwig interprets this as nine-and-a-half zeros, i.e. $10/0^1/_2$*] is the coarsest kind; then follow 9/0, $8/0^1/_2$, 8/0, and so forth as far as 2/0, $0^1/_2$, 0, and further 1, $1^1/_2$, 2, $2^1/_2$, as far as $6^1/_2$, 7.'[127]

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126 '*Die hiesigen wie die nürnberger Saiten haben zwischen a und b nur 6 Nummern, und wenn man auch halbe Nummern einschaltet, so hat man doch nur 15 Nummern, deren halbe Nummern zu Irrungen Anlass geben.*' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII,* Leipzig, November 1811, 74. It is interesting to note Bleyer's use of the principle of geometric proportion. We shall return to this subject below. By saying six gauges between a and b Bleyer is not counting the first and last gauges (the gauges at a and b): including these two there are a total of eight whole gauges starting with gauge 5/0 (0.83mm) and ending with gauge 3 (0.41) which, when the intermediate half gauge are included gives a total of 15 gauges from 5/0 to 3.

127 See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 100-101. The translation given here is by Hellwig. He gives his source as the article '*Draht*' by Karmarsch in Johann Joseph Prechtl, *Technologische Enzyklopädie oder alphabetisches Handbuch der Technologie* ..., vol. 4, Stuttgart 1833, 149-50.

One piano by Schantz (Sz/11) of about 1815 is marked with every possible half gauge between gauge 3/0 and gauge 4. In such an isolated instance and in the absence of any original strings it is not possible to conclude whether the wire intended was sorted according to some new system or according to the Nuremberg system consistently interpolated with half gauges.

If the presence of half gauge markings does not preclude the Nuremberg system, the absence of half gauges does not necessarily imply the Nuremberg system. Other systems without half gauges could have existed alongside the Nuremberg system.

iii) Thomée's diameters for the Nuremberg gauge system

The well-known set of diameters for the Nuremberg system reported by Thomée in his *Untersuchungen über Draht- und Blechlehren* of 1866, given here in table 8, does not entirely follow a geometric progression.[128] These diameters for the Nuremberg

128 See H. Thomée, 'Untersuchungen über Draht- und Blechlehren', *Zeitschrift des Vereines Deutscher Ingineure*, X, 1866, 659-60. Remy Gug already noted that Thomée's equivalents do not follow a geometric progression. See 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne* , 18, 1984, 52. In his article 'Stringing Materials and Gauges for Clavichords by I. C. Gerlach and H. A. and J. A. Hass', *De Clavicordio, Proceedings of the International Clavichord Symposium*, Magnano 1993, 123-33, Grant O'Brien shows that the Nuremberg system, as interpreted by Thomée does follow a single geometric progression (page 129). However, O'Brien only takes account of the gauges from 3/0 to 8. The thicker gauge equivalents given by Thomée do not follow a geometric progression. I would reject O'Brien's fifth criterion (pages 128-9) for the originality of strings, that as a whole, a gauge system should have a drawing ratio close to 5/4. Other drawing ratios, more than one ratio and the lack of a ratio at all are all possibilities.

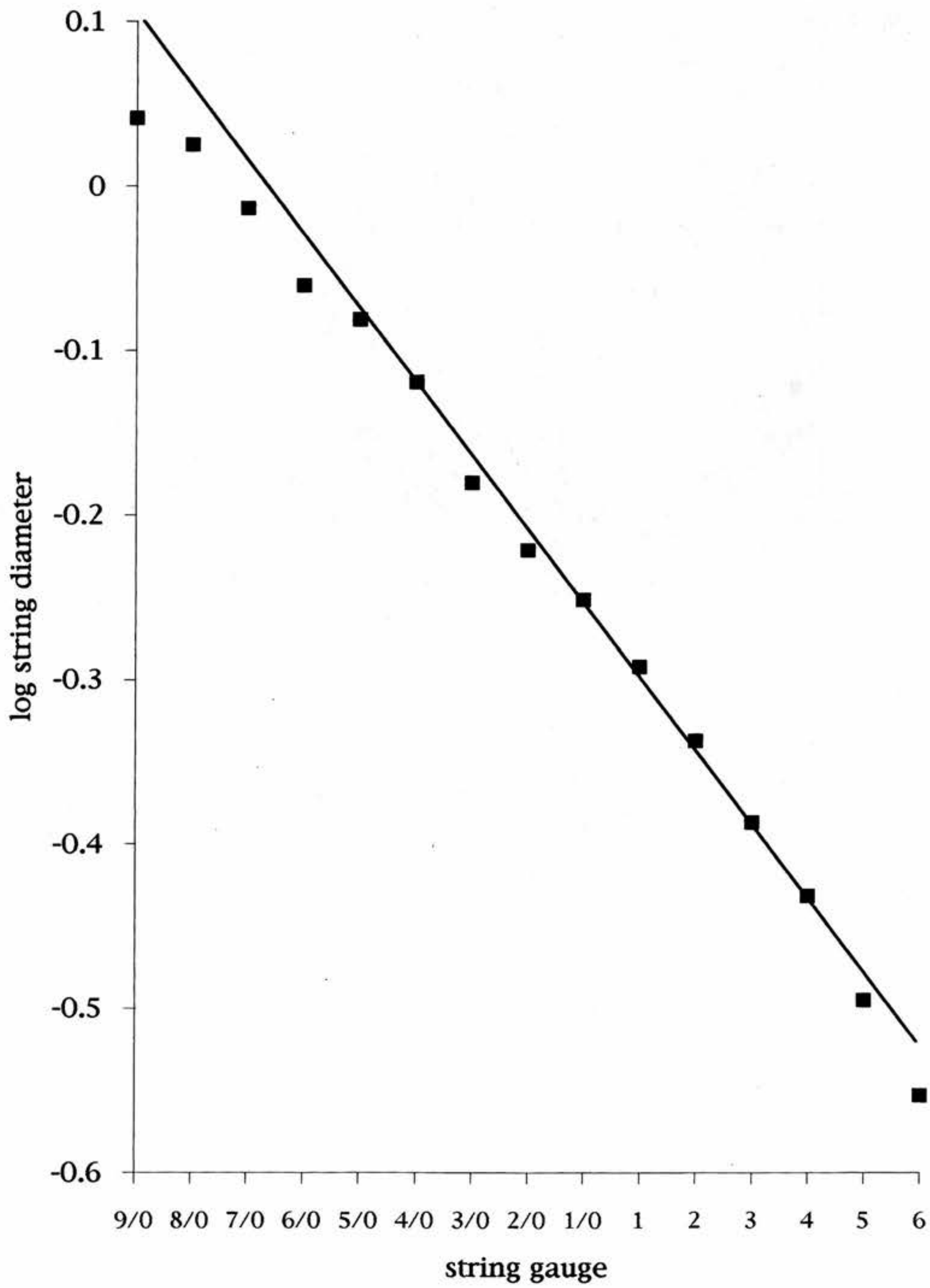
system are plotted logarithmically against gauge number in graph 2. Only the thinner sizes, from gauge 5/0 to gauge 6, more or less follow a geometric progression. A regression analysis of Thomée's values for these thinner gauges gives the ratio 1 : 1.111 between the successive diameters when fitted to a geometric progression. The fitted values of gauges 9/0 to 6 have been calculated according to this ratio and are compared with the diameters given by Thomée in table 9.

The Nuremberg gauge system
diameters (Thomée)

Gauge	mm
9/0	1.10
8/0	1.06
7/0	0.97
6/0	0.87
5/0	0.83
4/0	0.76
3/0	0.66
2/0	0.60
1/0	0.56
1	0.51
2	0.46
3	0.41
4	0.37
5	0.32
6	0.28

Table 8

Nuremberg string diameters (Thomée) plotted logarithmically against gauge numbers



graph 2

Thomée's diameters for the Nuremberg gauge system
compared with the fitted diameters based on
the actual diameters of gauges 5/0 to 6

Gauge	Thomée mm	Fitted mm
9/0	1.10	1.279
8/0	1.06	1.152
7/0	0.97	1.037
6/0	0.87	0.933
5/0	0.83	0.838
4/0	0.76	0.756
3/0	0.66	0.680
2/0	0.60	0.612
1/0	0.56	0.551
1	0.51	0.496
2	0.46	0.446
3	0.41	0.402
4	0.37	0.362
5	0.32	0.326
6	0.28	0.293

Ratio between successive fitted diameters 1 : 1.111

Table 9

No reason has yet been found why the largest four gauge diameters given by Thomée do not conform to the geometric progression which the other gauge diameters more or less follow. It could be suggested that we have no guarantee for the reliability of Thomée's diameters for the Nuremberg system; after all, he does not give his sources for them and may, for instance, have measured the diameters of strings which were later replacements. Huber has shown however that the diameters of the strings on a small number of old instruments do conform to Thomée's equivalents.[129] These include one instrument by Könnicke (1796), one by Walter (W/c.1800d) and one by Brodmann (c.1810).[130] More pianos with strings conforming to Thomée's Nuremberg system are presented here.

iv) Evidence for Thomée's Nuremberg system: Hofmann

Seven pianos by Hofmann (H/c.1785a, H/c.1785c, H/c.1790b, H/c.1795c, H/c.1800, H/c.1805 and H/c.1820) still retain some old strings which could be thought to be original on the basis of the criteria listed above: the consistency of the loops at the hitch-pins;

129 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 199 and 212.

130 The instrument by Brodmann is {Vienna} and the one by Könnicke is K/5. See also Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 1990, 198-9 and 212.

the consistency of the coils on the tuning-pins and the consistency of the string diameters within each group of notes as defined by the string gauge markings. The strings found on H/c.1820, which appear to conform to another system, Huber's 'Berlin' system, are discussed below. Of the remaining six, H/c.1800 is the only piano with strings which fulfill the criterion, also in the list above, which stipulates that amongst a set of old strings at least some can be expected to have an irregular cross-section owing to the deformation of the dies used for drawing down the wire.

In table 10 the diameters of the old strings of these six pianos are compared with Thomée's diameters for the Nuremberg system. The measurements of the long and the short axes of the oval strings of H/c.1800 have been averaged for each gauge.[131]

131 The author is grateful to David Hunt for the measurements of the strings of H/c.1800. The author was unable to confirm the measurements of H/c.1785a which were kindly given to the author by the owner of the instrument. The measurements of the diameters given for the other instruments in table 11 were made by the author.

Gauge sizes and diameters of old strings on six pianos
by Hofmann
compared with the Nuremberg (Thomée) system

Thomée	H/	c.1785a	c.1785c	c.1790b	c.1795c	c.1800	c.1805
0.97	7/0	1.02	1.15	1.05	1.02	0.99	-
0.87	6/0	0.92	0.93	0.95	?	0.94	-
0.83	5/0	0.85	0.86	0.84	0.84	0.85	0.85
0.76	4/0 brass	-	0.78	0.78	0.78	0.78	0.75
0.76	4/0 iron	0.81	0.82	-	0.82	0.78	0.80
0.66	3/0	0.71	-	-	0.71	0.68	0.72
0.60	2/0	0.61	-	-	0.63	0.59	0.64
0.56	1/0	0.57	-	-	0.61	-	0.57
0.51	1	0.54	-	-	0.53	-	0.53
0.46	2	0.51	-	-	0.52	-	-
0.41	3	0.44	-	-	-	-	-
0.37	4	0.37	-	-	-	-	-

Table 10

From their decoration and on diverse organological grounds these six instruments can be dated variously between 1785 and 1805. Their stringing schemes are similar to each other and, taken in chronological order, show a gradual tendency towards slightly heavier stringing in the treble while maintaining the same stringing scheme in the bass. None of the six has a stringing scheme of a character which suggests the adoption of a new system. There is thus little doubt that all six pianos were originally strung according to the same system, presumably the Nuremberg system.

Only H/c.1800 and possibly H/c.1785a, however, have strings of diameters which agree with Thomée's diameters for the Nuremberg system. Most of the old strings on the other four pianos are thicker than in Thomée's report. Two possible explanations present themselves for this discrepancy. The first is that the wire as delivered to Hofmann did not accurately correspond to the gauge system to which it was then supposed to belong. This view is supported Bleyer's criticism (1811) of the wire drawers and their clients:

> 'Whoever allows himself to trust and believe in the wire manufacturers is often scandalously deceived. Not that they lack the willingness, no, but because their clients are not so critical, so that two gauges of wire often have the same thickness and one gauge often comprises two thicknesses. Furthermore, it is easy to convince oneself that not all manufacturers observe a standard measure.'[132]

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132 '[...]*denn wer sich auf Treu und Glauben der Drahtfabrikanten verlässt, wird oft schändlich betrogen. Nicht weil es ihnen an Geschicklichkeit fehlt, nein, sondern weil ihre Abnehmer es so genau nicht nehmen, so*

The second possible explanation for the discrepancy between the gauges marked on the pianos of Hofmann and their measured diameters is that the pianos were later re-strung with strings of larger diameters.

If we accept for the moment that the strings on H/c.1800 are original, that the other five pianos have been re-strung and that the instruments by Hofmann built between 1785 and 1805 were strung according to the same system it follows that Hofmann's early pianos, that is, those made up to about 1805, were all strung according to the system to which the strings found on H/c.1800 conform, Thomée's Nuremberg system. It also follows that H/c.1800, and by extension Hofmann's early pianos in general, provide evidence for the use of Thomée's diameters for the Nuremberg system up to 1805 in Vienna.

v) Evidence for the use of Thomée's Nuremberg system: Nannette Streicher

There are two early instruments by Streicher each of which has a large proportion of old and possibly original strings conforming to

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findet man oft unter zwey Nummern einerley und unter einer Nummer zweyerley Dicken der Saiten. Dass ferner nicht alle Fabriken einerley Mass beobachten, davon kann man sich sehr leicht überzeugen.' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII*, Leipzig, November 1811, 74.

the thicknesses given by Thomée for the Nuremberg system. One of these pianos, S/c.1804b, has no gauge markings. The other, with gauges markings, is S/1807/733.

In the history of the pianos of the Streicher firm there is a long period of at least thirty years starting at the beginning of the nineteenth century in which the hitch-pin loops of the strings usually take a particular form, reminiscent of the loops of the strings found in the English grand pianos by the Broadwood firm. These loops are different from those found in the instruments of other makers working in the Viennese and southern German traditions and they offer an additional criterion for assessing the originality of the strings in a piano by Streicher. The short end of the hitch-pin loop doubles back in a figure of eight. The old strings on S/c.1804b have such loops. Furthermore, although there are no gauge markings on this piano, the positions at which the strings change diameter correspond to the positions of the gauge changes marked on the wrestplank of another remarkably similar piano by Streicher, S/c.1804a (table 11).

Comparison of the string lengths of S/c.1804a and S/c.1804b and of the gauge markings on S/c.1804a with the diameters of the strings on S/1804b

	String lengths				Lengths c.1804b minus c.1804a	Gauges marked on c.1804a	Thomée's diameters for gauges on c.1804a	Actual diameters c.1804b (*italics = later strings)*	Presumed gauges for c.1804b
	c.1804a		c.1804b						
	mm	Zoll	mm	Zoll	mm				
FF	1678	63.8	1680	63.8	2	7/0	0.97	0.98	7/0
	1662	63.1	1664	63.2	2		0.97	0.98	
	1643	62.4	1646	62.5	3	6/0	0.87	0.9	6/0
	1624	61.7	1627	61.8	3		0.87	0.9	
	1605	61.0	1608	61.1	3	5/0	0.83	0.83	5/0
	1582	60.1	1584	60.2	2		0.83	0.83	
	1555	59.1	1558	59.2	3	4/0	0.76	0.75	4/0
C	1528	58.1	1530	58.1	2		0.76	0.75	
	1491	56.7	1494	56.8	3		0.76	0.75	
	1450	55.1	1452	55.2	2		0.76	0.75	
	1411	53.6	1414	53.7	3	3/0	0.66	0.67	3/0
	1370	52.1	1375	52.2	5		0.66	0.67	
F	1331	50.6	1338	50.8	7		0.66	0.67	
	1288	48.9	1296	49.2	8	3/0	0.66	0.67	3/0
	1247	47.4	1258	47.8	11		0.66	0.67	
	1202	45.7	1211	46.0	9		0.66	0.67	
	1161	44.1	1172	44.5	11	2/0	0.6	0.59	2/0
	1120	42.6	1129	42.9	9		0.6	0.59	
	1079	41.0	1089	41.4	10		0.6	0.59	
c	1038	39.4	1048	39.8	10	1/0	0.56	0.54	1/0
	997	37.9	1010	38.4	13		0.56	0.54	
	959	36.4	969	36.8	10		0.56	0.54	
	923	35.1	932	35.4	9		0.56	0.54	
	881	33.5	890	33.8	9		0.56	0.54	
f	841	32.0	851	32.3	10		0.56	0.54	
	804	30.5	813	30.9	9	1	0.51	0.5	1
	766	29.1	775	29.4	9		0.51	0.5	
	730	27.7	738	28.0	8		0.51	0.49	
	693	26.3	700	26.6	7		0.51	0.49	
	655	24.9	663	25.2	8		0.51	0.49	
	620	23.6	626	23.8	6		0.51	0.49	
Gap spacer with dummy strings							0.51	0.49	

Table 11

Comparison of the string lengths of S/c.1804a and S/c.1804b and of the gauge markings on S/c.1804a with the diameters of the strings on S/1804b

	String lengths				Lengths c.1804b minus c.1804a	Gauges marked on c.1804a	Thomée's diameters for gauges on c.1804a	Actual diameters c.1804b (*italics* = *later*)	Presumed gauges for c.1804b
	c.1804a		c.1804b						
	mm	Zoll	mm	Zoll	mm				
Gap spacer with dummy strings									
c'	559	21.2	564	21.4	5	1	0.51	0.49	1
	528	20.1	533	20.3	5		0.51	0.49	
	502	19.1	506	19.2	4		0.51	0.49	
	474	18.0	476	18.1	2		0.51	0.49	
	446	16.9	448	17.0	2		0.51	0.49	
f'	420	16.0	424	16.1	4		0.51	0.49	
	395	15.0	400	15.2	5		0.51	0.49	
	374	14.2	378	14.4	4		0.51	0.49	
	352	13.4	355	13.5	3		0.51	0.49	
	332	12.6	336	12.8	4	2	0.46	0.46	2
	313	11.9	316	12.0	3		0.46	0.46	
	295	11.2	298	11.3	3		0.46	0.46	
c''	278	10.6	281	10.7	3		0.46	0.46	
	262	10.0	265	10.1	3		0.46	*0.51*	
	246	9.3	250	9.5	4		0.46	*0.51*	
	232	8.8	235	8.9	3		0.46	*0.51*	
	219	8.3	222	8.4	3		0.46	*0.44*	
f''	206	7.8	208	7.9	2	3	0.41	*0.44*	3?
	194	7.4	197	7.5	3		0.41	*0.44*	
	183	7.0	186	7.1	3		0.41	*0.44*	
	172	6.5	175	6.6	3		0.41	*0.44*	
	162	6.2	165	6.3	3		0.41	*0.44*	
	154	5.9	157	6.0	3		0.41	*0.44*	
	145	5.5	148	5.6	3		0.41	*0.44*	
c'''	136	5.2	140	5.3	4		0.41	*0.41*	
	129	4.9	133	5.1	4	4	0.37	*0.39*	4?
	122	4.6	126	4.8	4		0.37	*0.39*	
	116	4.4	119	4.5	3		0.37	*0.34*	
	111	4.2	114	4.3	3		0.37	*0.34*	
f'''	104	4.0	107	4.1	3		0.37	*0.34*	
	99	3.8	102	3.9	3		0.37	*0.34*	
	95	3.6	98	3.7	3	5	0.32	*0.34*	5?
	90	3.4	93	3.5	3		0.32	*0.34*	
	86	3.3	89	3.4	3		0.32	*0.34*	
	82	3.1	84	3.2	2		0.32	*0.34*	
	78	3.0	80	3.0	2		0.32	*0.34*	
c''''	74	2.8	76	2.9	2		0.32	*0.34*	

Table 11 (continued)

Not only do these two pianos by Streicher have very similar scalings but their bridge pin and nut pin positions, measured perpendicular to the spine, are practically identical, making it clear that these two pianos were built to the same stringing design. The consistency of the changes of the string diameters of S/c.1804b with the positions of the gauges marked on S/c.1804a can thus be taken as additional evidence that the strings of S/c.1804b are original.

The other piano by Streicher with strings which appear to be original and conform to Thomée's diameters for the Nuremberg system is also in the Germanisches Nationalmuseum (S/1807/733). Made in 1807, this magnificent mahogany-veneered piano is the earliest dated Viennese piano known with a range of six-and-a-half octaves, from CC to f"". There are many old strings with the special figure-of-eight hitch-pin loops. The diameters of these strings (in relation to the gauges marked for them) conform to Thomée's diameters for the Nuremberg system. Table 12 gives the diameters as measured. In table 13 the average string diameters of S/c.1804b, taken as equivalents for the gauge markings of S/c.1804a and the average string diameters for each gauge marked on the 1807 piano are compared with Thomée's diameters for the Nuremberg system.

Diameters of the presumed original strings found on S/1807/733 compared with Thomée's diameters for the Nuremberg system

Note	Diameter mm	Diameter mm	Diameter mm	Gauge Average	Gauge marked	Thomée's equivalent mm
CC	1.42	1.43		1.43	11/0	
CC#	1.29	1.30		1.30	10/0	
DD	1.30	1.30				
DD#	1.30	1.30				
EE	1.14	1.13		1.14	9/0	1.10
FF	n/o	n/o		?	8/0	1.06
FF#	n/o	n/o				
GG	1.00	1.01		1.01	7/0	0.97
GG#	0.99	1.01				
AA	0.87	0.87		0.87	6/0	0.87
AA#	0.87	0.87				
HH	n/o	0.83		0.83	5/0	0.83
C	0.82	n/o				
C#	-	-		?	4/0	0.76
D	-	-				
D#	-	-	-		3/0	0.66
E	0.73	-	-			
F	-	-	-			
F#	0.66	0.69	0.68	0.68	3/0	0.66
G	0.69	0.67	0.69			
G#	0.69	0.67	0.66			
A	-	0.61	0.63	0.61	2/0	0.60
A#	0.62	0.62	0.61			
B	0.61	0.60	-			
c	0.54	0.55	0.55	0.55	1/0	0.56
c#	0.56	0.55	0.56			
d	0.54	0.55	-			
gap spacer	0.56	0.55	0.56			
d#	0.56	0.56	0.55			
e	0.55	0.55	0.55			
f	0.56	0.55	0.55			
f#	-	0.56	0.56			
g	0.56	0.54	0.54			
g#	0.54	0.54	0.54			
a	-	0.55	0.55			
a#	0.55	0.56	0.55			
b	0.55	0.56	0.55			

Note	Diameter mm	Diameter mm	Diameter mm	Thomée's Average	Gauge marked	Gauge equivalent mm
c'	0.55	0.55	0.56	(0.55)	(1/0)	(0.56)
c#'	0.56	0.55	0.56			
d'	0.55	0.56	-			
d#'	-	0.56	0.55			
e'	0.56	0.56	0.55			
f'	0.54	0.54	0.56			
f#'	0.56	-	0.56			
g'	0.50	0.50	0.51	0.49	1	0.51
g#'	-	-	0.50			
a'	0.50	0.50	-			
a#'	0.50	-	0.50			
b'	-	-	-			
c"	-	0.48	0.50			
c#"	-	-	0.49			
d"	0.49	0.49	0.49			
gap spacer	0.49	0.49	0.49			
d#"	0.49	0.49	0.49			
e"	0.49	0.49	0.49			
f"	0.49	0.49	0.49			
f#"	0.48	0.48	0.50			
g"	-	0.49	0.49			
g#"	-	0.49	-			
a"	-	-	-			
a#"	-	-	-			
b"	rest	not	original			
c"'						

Table 12

Two pianos by Streicher
Gauge diameters compared with Thomée's diameters for the Nuremberg system

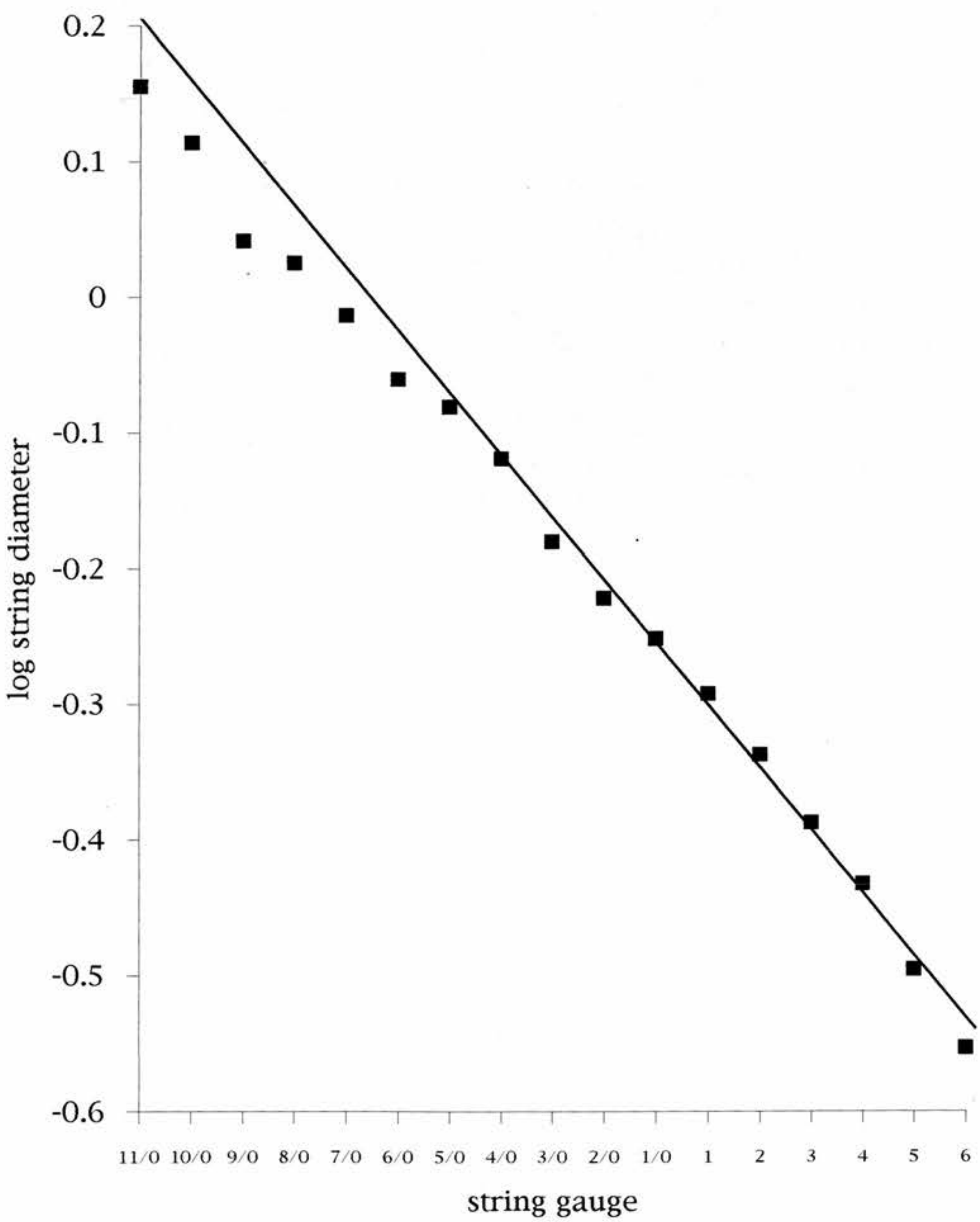
	S/1807/733	S/c.1804b	Nuremberg (Thomée)
Gauge	mm	mm	mm
11/0	1.43	-	-
10/0	1.30	-	-
9/0	1.14	-	1.10
8/0	?	-	1.06
7/0	1.01	0.98	0.97
6/0	0.87	0.90	0.87
5/0	0.83	0.83	0.83
4/0	?	0.75	0.76
3/0	0.68	0.67	0.66
2/0	0.61	0.59	0.60
1/0	0.55	0.54	0.56
1	0.49	0.49	0.51
2	?	0.46	0.46
3	-	?	0.41
4	-	?	0.37
5	-	?	0.32

Table 13

The strings on these two instruments show that Streicher used wire conforming to Thomée's diameters for the Nuremberg system until at least 1807. Another instrument by Streicher built in 1811 (S/1811/902) has a stringing scheme practically the same as that of the piano of 1807. If we then assume that both the 1807 and the 1811 pianos were strung according to the same system we can say that Streicher used string diameters conforming to Thomée's interpretation of the Nuremberg system, although not necessarily exclusively, until at least 1811.

Thomée's list of diameters for the Nuremberg system does not include gauges thicker than 9/0 although thicker gauges were used for the low bass notes of the larger pianos made at the beginning of nineteenth century. From the diameters of the strings of the 1807 piano marked for gauges 11/0 and 10/0 we can tentatively extend Thomée's diameters for the Nuremberg system. Like the thicker gauges given by Thomée, the diameters of the strings for gauges 11/0 and 10/0 on the 1807 piano do not follow the geometric progression to which the thinner gauges conform (graph 3).

Nuremberg string diameters (Thomée) plotted logarithmically against gauge numbers extended to include the diameters of the strings marked for gauges 11/0 and 10/0 found on S/1807/733



graph 3

vi) Thomée's Nuremberg gauge system: summary

Two pianos by Streicher and one by Hofmann, all three of the first decade of the nineteenth century, appear to have original strings corroborating Thomée's diameters for the Nuremberg system. The strings of these three instruments also confirm the use of Thomée's Nuremberg system by prominent Viennese builders until at least 1811. Nevertheless, the evidence from the handful of instruments so far found by Huber, augmented by these three instruments, hardly provides a large enough sample on which to base any generalisations about the Nuremberg system and its use.

Jakob Reinhard Erhard's system

That the wire produced in Nuremberg was not always sorted according to the Nuremberg system is illustrated by an announcement published by a Nuremberg wire drawer, Jakob Reinhard Erhard, in 1793.[133] His system consisted of 36 spools each of which was marked not by gauge but by note name; each spool was inscribed with the names of the notes for which the wire of that spool was to be used. The 36 spools were for a five-octave piano (61 notes), so it follows that most of the spools were

133 *Intelligenzblatt der allgemeinen Literaturzeitung Nr. 93*, 1793, 743. Quoted in Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 69 and Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 200.

intended for only one or two notes. The differences in thickness between one gauge and the next were thus considerably smaller than in the Nuremberg system.

The main point of interest here is that the wire was made in Nuremberg but not sorted according to the Nuremberg system. It is also interesting to note that Erhard, the wire drawer, not only chose which gauges were to be used for which notes, rather than leaving the choice to the piano maker, but also did not take scaling into account. The different piano makers used different stringing schemes and certainly did take scaling into account. One can therefore question whether Erhard was taken seriously in his day.

Jakob Bleyer's system

In 1811, Jakob Bleyer advertised a half gauge system in which he designated the gauges only by whole numbers.

> 'We calibrated our fork-shaped string-measuring gauge in the following manner. Between two strings, a and b, with diameters in the ratio 1 : 2, 15 divisions are made, and in such a way that when one arranges all the diameters in the right order a geometric series emerges. The string thicknesses must increase and decrease in a geometric proportion if the tone of the instrument is to be even. Thus we have 17 gauges from a to b. Today's strings, like those of Nuremberg, only have 6 gauges between a and b, and if one admits half gauges, one only has 15 gauges of which the half sizes give rise to error.'[134]

134 '*Wir gaben unserer gabelförmigen Saitenlehr folgende Einrichtung. Zwischen zwey Saiten a b, deren Durchmesser sich verhalten = 1:2 sind 15*

The advantage of his extra two gauges is not great and hardly provide grounds for a claim to have made an improvement. Bleyer's system can be best understood not as a new system but as the Nuremberg system, improved in three ways. First, he improved the Nuremberg system by consistently interpolating intermediate gauges between the existing ones. Second, he gave the gauges a new nomenclature to avoid the confusion of the half gauges names. Bleyer's objection to 'half gauges' makes it clear that his system comprised only whole number denominations. Third, and most important, he rationalised the diameters to fit a geometric progression. In making this third improvement Bleyer added two extra gauges. That Bleyer's system is similar to the Nuremberg system is reflected in the similarity of their two gaüge ratios. The Nuremberg system, in its interpretation by Thomée and taken from gauge 5/0 to gauge 6, exhibits a gauge ratio of 1 : 1.111.

Stufen eingeschaltet, und zwar so, dass, wenn man alle Saiten-Durchmesser in gehöriger Ordnung hinschreibt, eine geometrische Reihe zum Vorschein kömmt. Im geometrischem Verhältnisse müssen die Saiten-Dicken zu- und abnehmen, wenn die Töne des Instruments gleichförmig klingen sollen. Wir haben also von a bis b = 17 Nummern. Die hiesigen wie die nürnberger Saiten haben zwischen a und b nur 6 Nummern, und wenn man auch halbe Nummern einschaltet, so hat man doch nur 15 Nummern, deren halbe Nummern zu Irrungen Anlass geben.' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII,* Leipzig, November 1811, 74. By saying six gauges between a and b Bleyer is not counting the first and last gauges (the gauges at a and b). If the first and last are included there are a total of eight whole gauges starting with gauge 5/0 (0.83mm) and ending with gauge 3 (0.41) which, when the intermediate half gauge are included as well gives a total of 15 gauges from 5/0 to 3. Bleyer's main claim for having found a new system is not strong. There is surely no great difference between his 17 gauges and the 15 gauges of the Nuremberg system (including half gauges) as he describes it.

Bleyer's system, taking every other gauge (equivalent to the Nuremberg whole gauges) has by definition a gauge ratio of 1 : 1.091.

One surviving upright grand piano of about 1815 by Bleyer and his colleague Joseph Wachtl has gauge markings which could refer to Bleyer's system. This instrument has 18 different gauges marked in ink on the nut and the system used appears to comprise 20 gauges.[135] These begin with 9/0 for FF and 8/0 for FF#. They change every subsequent two notes as far as BB which is marked for 3/0. 2/0 is then marked at C, 1/0 at D and 1 at E. Apparently, these gauges all indicate brass. The changeover to iron occurs at F#, where gauge 1 is repeated. Thereafter comes gauge 2 at A and gauge 3 at c. A jump to gauge 6 at d# is followed by gauge 7 at a, gauge 8 at f#', gauge 9 at d#", gauge 10 at c"' and finally gauge 11 at a"'. It is not clear why gauges 4 and 5 were omitted. In any case, Bleyer and Wachtl obviously used gauge numbers of their own here and did not follow the traditional Nuremberg gauge numbering system.

In his description of his gauge system, Bleyer does not mention the total number of gauges he uses, only that between two gauges, one of which is half the diameter of the other, he has 17 gauges. The system of 20 gauges used on the upright grand piano could be these 17 augmented by three extra ones, either thicker or thinner. 17 gauges in Bleyer's system cover the same diameter range as 15 gauges in the Nuremberg system so 20 gauges in

135 {Budapest}.

Bleyer's system are very nearly equivalent to 18 half gauges in the Nuremberg system. If we then calculate on the assumption that gauge 9/0 in Bleyer's system is the same as gauge 9/0 in the Nuremberg system, the thinnest gauge used by Bleyer, gauge 11 would be about equivalent to gauge 1 in the Nuremberg system. This is a gauge often used as the thinnest gauge in Viennese grand pianos of the second and third decades of the nineteenth century, adding credibility to the idea that the upright grand piano by Wachtl and Bleyer was intended to be strung according to Bleyer's system announced in 1811.

Bleyer remarks that the use of a geometric progression for devising a string gauge system is to the advantage of the sound produced, that the quality of the sound depends on a mathematical principle. He then proceeds to rationalise the Nuremberg system. This perhaps reflects a new emphasis or belief in 'scientific' principles and a certain dissatisfaction with a reliance on the craftsman's tradition.

If it is true that a geometric progression in the gauge system improves the sound, the logical conclusion would be to devise a system with an individual gauge for the strings of each note. Perhaps it was a vague awareness of this idea which prompted Bleyer to see his 17 gauges as an improvement on a Nuremberg system with 15 gauges and which stimulated Erhard to devise his system in which a new gauge is used every two or three notes.

A piano by Brodmann of 1818: no system

The interpretation of a set of gauge markings on a piano with strings which are assumed to be original is beset with problems. The gauge system cannot be identified on the grounds of the presence or absence of half-gauge markings. The way wire was probably sorted, using a plate into which a set of slits was cut or a set of holes was drilled, means that each gauge consisted of a range of diameters.[136] Wear of the drawer's dies could have resulted in oval strings which may conform to a particular gauge when measured across one axis but not across the other. Contemporary sources relay to us that there was no guarantee that each spool of wire as delivered to the piano builder conformed throughout its length, or indeed at all, to the gauge indicated on the spool by the wire drawer. There is also no guarantee that the instrument builder kept to the gauges he himself had indicated on the piano in hand. These different problems all contribute to the difficulties involved when determining the system used by a particular builder even when an instrument has gauges marked and strings which appear to be original.

These problems are illustrated by the next instrument considered here which provides information on the subject of

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136 The same is almost certainly true of Bleyer's fork-shaped calliper. The two arms of the fork probably formed a V shape callibrated by lines crossing the V, each one marked for a gauge size. The wire would be inserted into the V until it touched on both arms. The nearest line on the V would then have indicated the gauge of the wire. In this way each gauge would presumably have covered the diameters from about halfway to the next gauge thinner to halfway to the next gauge thicker.

string gauge systems. This beautiful-sounding instrument by Joseph Brodmann was ordered in November 1817 and delivered to Schloß Wörlitz, Germany, in February 1818. It is of six-and-a-half octaves and in a quite remarkable state of preservation, having never left the castle for which it was made. The strings are not corroded and all but 11 of them (out of a total of 226) appear to be original. The diameter of each string, measured only at one point and across one axis are compared in table 14 with Thomée's Nuremberg diameters. Although the diameters of the strings might appear at first to conform to Thomée's Nuremberg diameters, especially in the extreme treble (gauge 3), there are places in which the strings are a gauge or more too thick (gauges 9/0, 8/0, 1/0 and 2). The strings used in the domains of some gauges have diameters which pass without discontinuity from one gauge to the next (3/0 to 2/0 and 2/0 to 1/0). At the start of gauge 5/0 Brodmann appears to have continued to use the previous gauge for one note. Plotting the averages of the diameters for each gauge logarithmically, even excluding the anomalies, reveals no convincing geometric progression. This is shown in graph 4 where the diameters found on the piano are compared with Thomée's Nuremberg diameters. Interestingly, the two thickest gauges (9/0 and 8/0) on {Wörlitz} appear to correct Thomée's diameters for these two gauges in his Nuremberg system, providing two diameters which fit the geometric progression followed by Thomée's thinner diameters for the Nuremberg system.

This example not only illustrates some of the problems involved but also shows that not every instrument with original strings will necessarily have strings conforming to a system with which we are familiar and, more importantly, that not all sets of original strings need necessarily conform to a geometric progression. In such cases our method of identifying and comparing gauge systems, that is, by their gauge ratios, fails us. These conclusions are especially relevant considering that another instrument by Brodmann of about 1810 ({Vienna}) is one of the instruments providing positive evidence for Thomée's interpretation of the Nuremberg gauge system.[137] Did Brodmann change gauge system? Did he become less critical of his supplier of music wire? Has the instrument been partially re-strung early in its life after all? No answers can be given to these questions.

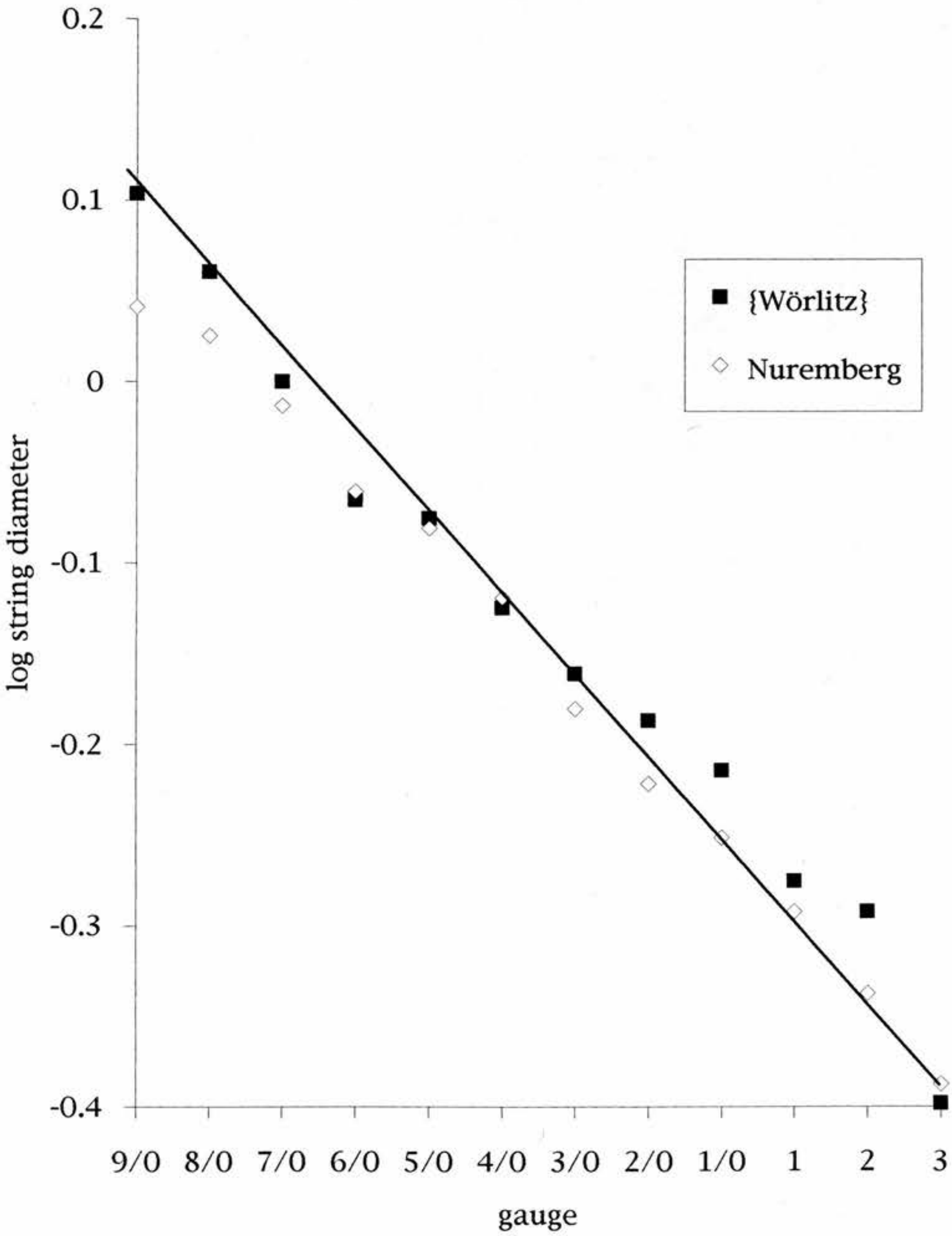
137 See Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 198-9 and 212.

Diameters of the original strings found on a
grand piano by
Joseph Brodmann ({Wörlitz})
compared with the diameters
for the Nuremberg system interpreted by Thomée

Diameter mm	Diameter average mm	Gauge marked	Gauge in mm N'berg	Note	Diameter mm	Diameter mm	Diameter mm	Diameter average mm	Gauge marked	Gauge in mm N'berg
	1.27	9/0	1.10	e'	0.61	0.63	0.61	(0.61)	(1/0)	(0.56)
				f'	0.59	0.61	0.62			
	1.15	8/0	1.06	f#'	0.64	0.61	0.60			
				g'	0.60	0.60	0.61			
				g#'	0.59	0.60	0.61			
				a'	0.58	0.60	0.59			
	1.00	7/0	0.97	a#'	0.61	0.61	0.60			
				b'	0.62	0.63	0.62			
0.86	0.86	6/0	0.87	c"	0.61	0.62	0.62			
0.85				c#"	0.61	0.61	0.59			
0.86	0.84	5/0	0.83	d"	0.63	0.59	0.59			
0.82				d#"	0.51	0.52	0.54	0.53	1	0.51
0.82	0.75	4/0	0.76	e"	0.52	0.54	0.53			
0.75				f"	0.52	0.55	0.55			
-				f#"	0.52	0.54	0.53			
0.67	0.69	3/0	0.66	g"	0.53	0.54	0.55			
0.71				g#"	0.54	0.55	0.51			
0.70		3/0	0.66	a"	0.51	0.53	0.54			
0.72				a#"	0.52	0.55	0.49			
0.68				b"	0.52	0.51	0.54			
0.73				c"'	-	0.52	-			
0.72				c#"'	-	0.61	0.61			
0.66				d"'	0.51	0.52	0.52	0.51	2	0.46
0.67				d#"'	0.50	0.52	0.52			
0.66				e"'	0.52	0.52	0.54			
0.69				f"'	0.55	0.54	0.54			
0.64	0.65	2/0	0.60	f#"'	0.55	0.55	0.53			
0.64				g"'	0.48	0.49	0.50			
0.63				g#"'	0.53	0.53	0.51			
0.63				a"'	-	-	-			
0.66				a#"'	0.50	0.50	0.51			
0.62				b"'	0.49	0.49	0.48			
0.63				c""	-	0.50	0.50			
0.63				c#""	0.50	0.49	0.50			
0.63				d""	0.48	0.50	0.47			
0.64				d#""	0.41	0.39	-	0.40	3	0.41
0.59	0.61	1/0	0.56	e""	0.39	0.41	-			
0.60				f""	0.39	0.38	-			
0.61										
0.63										

Table 14

Comparison of the diameters of the strings found on a piano by Brodmann of 1818 ({Wörlitz}) with Thomée's Nuremberg gauge diameters



graph 4

The Streicher 1819 system

It was seen above that two early instruments by Nannette Streicher, S/1804b and S/1807/733, both appear to be strung according to the Nuremberg gauge system as reported by Thomée. It was also suggested that owing to the uniformity of the stringing schemes on S/1807/733 and S/1811/902 Streicher was probably still using diameters corresponding to Thomée's Nuremberg system in 1811. In a piano built in 1819 the Streicher firm appears to have used another system, hitherto unrecognised, which I call the 'Streicher 1819 system'.

S/1819/1415 retains a large number of old strings assumed to be original on the basis on the usual criteria and the special criterion for the pianos of the Streicher firm, the presence of the figure-of-eight loops. Table 15 compares the diameters of the presumed original strings, averaged for each gauge, with Thomée's diameters for the Nuremberg system. The strings on S/1819/1415 have thicker diameters for the larger gauges and thinner diameters for the smaller gauges. The diameters of the strings fit a geometric progression reasonably well, suggesting that the strings do belong to a system (Table 16). In graph 5 the diameters of the Streicher 1819 system and those of Thomée's Nuremberg system are plotted logarithmically. The gauge ratio 1 : 1.159 for the Streicher system is significantly different from the Nuremberg ratio of 1 : 1.111 indicating that the two systems are distinct.

The diameters of the Streicher 1819 system compared with Thomée's diameters for the Nuremberg gauge system

	Thomée	Streicher 1819
Gauge	mm	mm
9/0	1.10	-
8/0	1.06	1.30
7/0	0.97	1.20
6/0	0.87	1.03
5/0	0.83	0.87
4/0	0.76	0.75
3/0	0.66	0.63
2/0	0.60	0.56
1/0	0.56	0.48
$1/0^1/_2$	-	0.45
1	0.51	-
2	0.46	-

Table 15

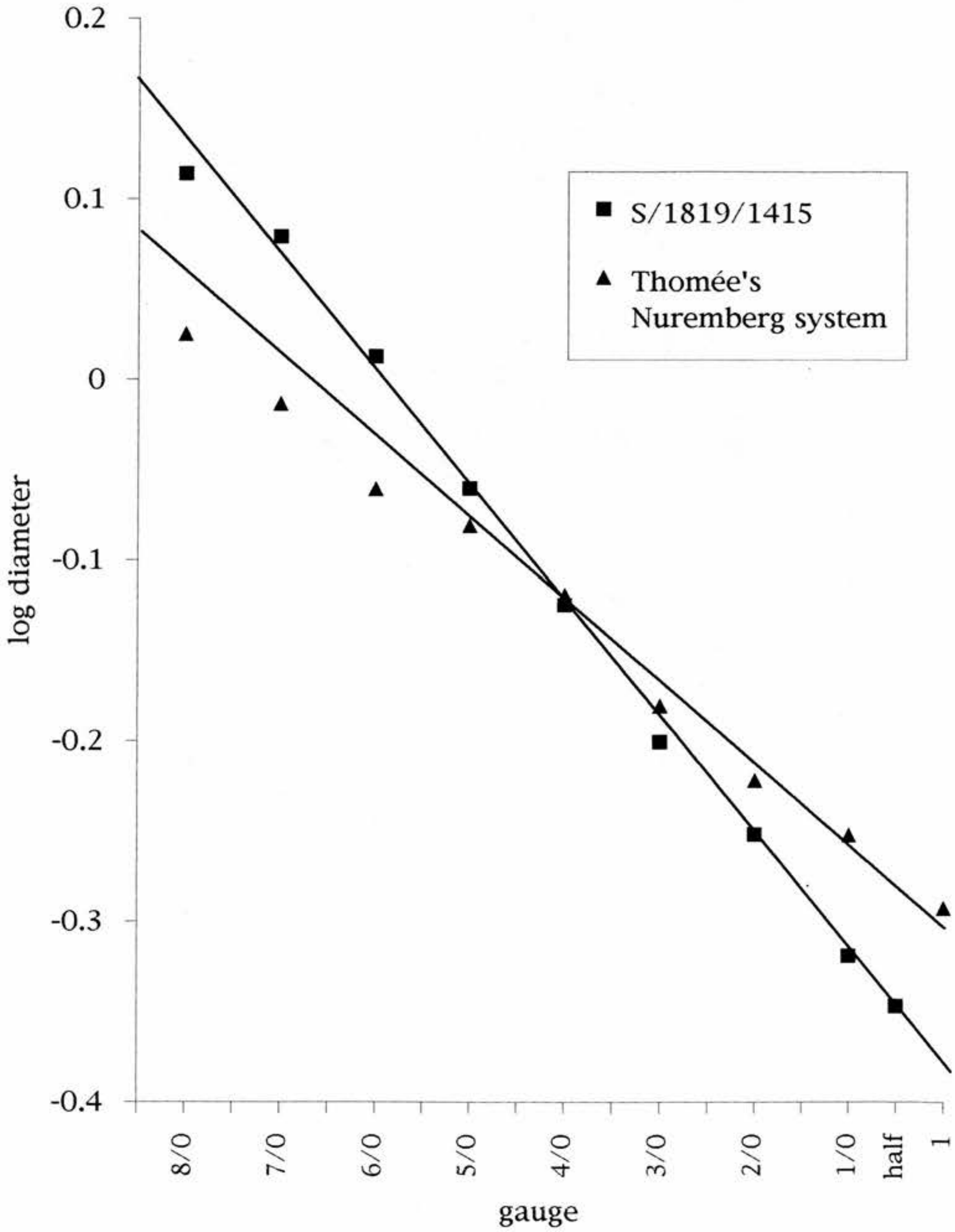
The diameters of the Streicher 1819 system
fitted to a geometric progression

	measured	fitted
Gauge	mm	mm
8/0	1.30	1.350
7/0	1.20	1.165
6/0	1.03	1.005
5/0	0.87	0.868
4/0	0.75	0.749
3/0	0.63	0.647
2/0	0.56	0.558
1/0	0.48	0.482
1/0½	0.45	0.447

Ratio between successive fitted diameters 1 : 1.159

Table 16

Comparison of the diameters of the strings found on a piano by Streicher of 1819 (S/1819/1415) with Thomée's Nuremberg gauge diameters



graph 5

Karmarsch's systems

Karl Karmarsch was born in Vienna and founded the Institute of Technology in Hannover.[138] Both in the *Jahrbücher des Kaiserlichen königlichen polytechnischen Institutes in Wien*, 1828, and in his article on wire ('*Draht*') in Joseph Prechtl's *Technologische Enzyklopädie*, 1833, Karmarsch describes two gauge systems intended for music wire.[139] The descriptions differ to such a degree that they both require scrutiny.

i) Karmarsch's reports of a gauge system used 'in Vienna'

The first part of the 1828 text by Karmarsch runs as follows:

> 'In Vienna, where today strings are made of such a good and usable quality that the formerly imported Nuremberg wire is no longer marketed at all, one designates the 17 gauges which are usually required by the following numbers: 8/0 (eight zeros), 7/0, 6/0, 5/0, 4/0, 3/0, 00 (two zeros), 0 (zero), 1, 2, 3, 4, 5, 6, 7, 8, 9. The last gauge is the finest of those mentioned. Sometimes, nevertheless, one has even thinner gauges, with higher numbers, and also thicker which, in order of increasing thickness are given the numbers 9/0, 10/0, 11/0, 12/0. The cross-section of all

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138 See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 100.

139 Karl Karmarsch, *Jahrbücher des Kaiserlichen königlichen polytechnischen Institutes in Wien*, 13 Band, Wien 1828, 169-72 and Johann Joseph Prechtl (ed.) *Technologische Enzyklopädie* (article *Draht*), vol. IV, Stuttgart 1833, 141-233 cited in Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 100-2.

these gauges increase roughly in a geometric progression of which the exponent is equal to 1.109.'[140]

Karmarsch then gives a table comparing the actual thicknesses of the wire with those calculated according to a geometric progression with the gauge ratio 1 : 1.109. This table is transcribed in table 17 with the diameters, given by Karmarsch in Viennese *Zoll*, translated into millimeters.[141] A regression analysis of the 'actual thicknesses' (*Wirkliche Dicke*) gives a gauge ratio of 1 : 1.120, slightly different from the ratio (1 : 1.109) Karmarsch used for computing his 'calculated thicknesses' (*Berechnete Dicke*).

Karmarsch neither states the origin of his actual diameters, nor how he arrives at his ratio of 1 : 1.109, nor why some gauges have no actual equivalents.[142] It is however of primary interest to note here that like Bleyer Karmarsch works on the assumption that a series of string diameters should fit a geometric progression.

140 '*In Wien, wo gegenwärtig Drahtsaiten so gut und brauchbar verferigt* [sic] *werden, daß die ehemals eingeführten nürnbergischen ganz ausser Handel gekommen sind, bezeichnet man die 17 Sorten, welche gewöhnlich begehrt werden, mit folgenden Nummern: 8/0 (acht Null), 7/0, 6/0, 5/0, 4/0, 3/0, 00 (zwei Null), 0 (Null), 1, 2, 3, 4, 5, 6, 7, 8, 9. Die letzte Sorte is von den genannten die feinste. Zuweilen indessen hat man noch feinere, von höheren Nummern, und auch gröbere, welche nach zunehmender Dicke die Nummern 9/0, 10/0, 11/0, 12/0 erhalten. Die Durchmesser aller dieser Sorten wachsen beinahe in einer geometrischen Reihe, deren Exponent = 1,109 ist.*' Karl Karmarsch, *Jahrbücher des Kaiserlichen königlichen polytechnischen Institutes in Wien,* 13 Band, Wien 1828, 169-70.

141 The equivalents used here for Viennese or Augsburg *Zoll* in millimeters are based on values given in Col. Cotty, *Aide-Mémoire à l'usage des Officiers d'Artillerie de France*, Paris 1819. The equivalent for the Viennese *Zoll* is given as 26.3186mm (p.899) and for the Augsburg *Zoll* as 24.6825mm (p.896). I am very grateful to Grant O'Brien for giving me this information.

142 On the basis of the thickest and the thinnest sizes (1.316mm and 0.211mm) and the number of steps required to arrive from one to the other (16) the '*Exponent*' would be 1.121, also not the same as 1.109.

Karmarsch's table (1828) for a system
used 'in Vienna'*

	Actual thickness	Calculated thickness	Fitted thickness
Number	mm	mm	mm
8/0	1.316	-	1.339
7/0	-	1.184	1.196
6/0	-	1.066	1.068
5/0	0.947	0.961	0.954
4/0	0.869	-	0.852
3/0	-	0.782	0.761
2/0	0.684	0.705	0.680
1/0	-	0.637	0.607
1	0.553	0.574	0.542
2	-	0.516	0.484
3	0.421	0.466	0.432
4	-	0.421	0.386
5	0.342	0.379	0.345
6	-	0.342	0.308
7	0.290	0.308	0.275
8	-	0.276	0.246
9	0.211	0.250	0.219

Karmarsch stated that he used the gauge ratio 1 : 1.109 for the calculated thickness

The actual thicknesses given by Karmarsch have a fitted gauge ratio of 1 : 1.120

* The thicknesses given by Karmarsch are in *Zoll*. I have converted them here to mm.

Table 17

In the 1833 source Karmarsch repeats his 1828 text in a summarised form, providing no new information:

> 'In Vienna, where presently wire strings are made equal in quality to those of Nuremberg, one has them in 17 sorts of the numbers 8/0, 7/0 as far as 2/0, 0, 1, 2, as far as 9. The thickness of Nro. 8/0 is 0.050 Zoll [1.316mm], that of Nro. 9 however 0.008 Zoll. [0.211mm]'[143]

ii) Karmarsch's first report of a system for sorting Nuremberg wire, the 'Nuremberg 1' system

The other sort of wire to which Karmarsch refers in the sources of 1828 and 1833 is Nuremberg wire. The 1828 description of a sorting system for Nuremberg wire, which I shall call Karmarsch's 'Nuremberg 1' system, is given after the description of the strings used 'in Vienna'.

> 'The Nuremberg piano strings of iron, famous for their excellence, usually come in 16 gauges, from No. 4/0 to number 11. The thickest gauge (4/0) has 115 as metric number, that is, 115 meters weigh $^1/_2$ kilogramme, or $407^1/_2$ [sic] Viennese feet for one Viennese pound; the finest, no. 11, is for the same weight 28 times as long so that its metric number is 3221. From this we can conclude that the thickness of no. 11 is about 0.0054 inches [0.0054 Viennese *Zoll* = 0.142mm] and that that of no. 4/0 must be 5.3 times as thick again, namely 0.0286 inches [0.753mm]. The exponent of the geometric progression according to which the the cross-section increases from the thinnest

143 See See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 101. The translation given here is by Hellwig. The millemeter equivalents are mine and based on a Viennese inch of 26.3186mm. Karmarsch used the Viennese inch in 1828.

must equal $^{15}\sqrt{5.3}$ which is 1.118.'[144]

Karmarsch appears to have made a small mistake here. There are only 15 gauges starting with gauge 4/0 and ending with gauge 11. These are:

4/0, 3/0, 2/0, 1/0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

There are thus 14 steps between gauge 4/0 and gauge 11 so that Karmarsch should have taken the fourteenth root of 5.3. Recalculating on the assumption that there were 15 gauges and that for a given weight the diameter of the thickest gauge was $\sqrt{28}$ times as thick as the thinnest gives a diameter ratio between successive gauges of 1 : 1.126. For purposes of comparison we can calculate the theoretical diameter of gauge 8/0 by extrapolation. Using the ratio 1 : 1.126 and Karmarsch's diameter for gauge 4/0 of 0.753mm [0.0286 *Zoll*] gives a diameter for gauge 8/0 of 1.210mm.

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144 '*Die wegen ihrer Vortrefflichkeit berühmten eisernen Nürnberger Klaviersaiten kommen gowöhnlich in 16 Sorten von Nro. 4/0 bis Nro. 11 vor. Die gröbste Sorte (4/0) hat zur metrischen Nummer 115, d.h. es gehen 115 Meter auf $^{1}/_{2}$ kilogramme, oder $407^{1}/_{2}$ [sic] Wiener Fuß auf das Wiener Pfund; die feinste, Nro. 11, ist bei gleichem Gewichte genau 28 Mahl so lang, indem ihre metrische Nummer 3221 beträgt. Hieraus läßt sich ableiten, daß die Dicke von Nro. 11 ungefähr 0,0054 Zoll, und jene von Nro. 4/0 das 5,3 fache, nähmlich 0,0286 Zoll betragen muß. Der Exponent der geometrischen Progression, nach welcher die Durchmesser von der feinsten Sorte an zunehmen, muß = $^{15}\sqrt{5{,}3}$ d.i. = 1,118 seyn.*' Karl Karmarsch, *Jahrbücher des Kaiserlichen königlichen polytechnischen Institutes in Wien*, 13 Band, Wien 1828, p.170-71.

iii) Karmarsch's second report of a system for sorting Nuremberg wire, the 'Nuremberg 2' system

In the 1833 source Karmarsch describes a different way of sorting the Nuremberg wire which I shall call his 'Nuremberg 2' system. Not only are there more gauges but half gauges as well. Here the Nuremberg wire is described before the wire used 'in Vienna' rather than after:

> 'Amongst the fine wires are *Claviersaiten* which are drawn mostly by their own workmen from coarser wires on handwheels (without further annealing), and which are numbered in a peculiar way when sold. The Nuremberg strings famed for their excellent quality exist in 31 sorts which are marked by numbers in the following way: 9/0½ is the coarsest kind; then follow 9/0, 8/0½, 8/0, and so forth as far as 2/0, 0½, 0, and further 1, 1½, 2, 2½, as far as 6½, 7. At Nro. 9/0½ the thickness is 0.039 *Zoll* [1.026mm]; at Nro. 7 only 0.008 *Zoll* [0.211mm]'[145]

145 See See Friedemann Hellwig, 'Strings and Stringing: Contemporary Documents', *Galpin Society Journal*, XXIX, 1976, 100-101. The translation given here is by Hellwig. He gives his source as the article '*Draht*' by Karmarsch in Johann Joseph Prechtl, *Technologische Enzyklopädie oder alphabetisches Handbuch der Technologie* ..., vol. 4, Stuttgart 1833, 212-3. The millemeter equivalents are mine and based on the Viennese inch which Karmarsch used in 1828. Alfons Huber, in 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 201, gives part of the original text in German: '*Die wegen ihrer vorzüglichen Beschaffenheit berühmten Nürnbergischen Claviersaiten kommen in 31 Sorten vor, welche mit Nummern auf folgende Art bezeichnet werden: 9/0½ is die gröbste Sorte; dann folgen 9/0, 8/0½, usf. bis 2/0, 0½, 0 ferner 1, 1½, 2, 2½, bis 6½, 7. Bei Nr. 9/0½ beträgt die Dicke 0.039 Zoll; bei Nr. 7 nur 0.008 Zoll.*' In his translation Hellwig gives 13 sorts, not 31. I have followed Huber here, assuming 13 to be a misprint. Counting from 9/0½ to 7 there are indeed 31 gauges if the two extreme gauges are included.

'$9/0^1/_2$' is assumed here to be equivalent to the more usual notation for the gauge a half size thicker than gauge 9/0, '$10/0^1/_2$'.

On the basis of Karmarsch's figures the whole gauge ratio for the Nuremberg 2 system is 1 : 1.104 whereas the actual diameters Karmarsch gives for the Nuremberg 1 system give a gauge ratio of 1 : 1.126. The absolute diameters for each gauge also differ between the two systems. For instance, the diameter for gauge 4/0 is 0.596mm in the Nuremberg 2 system and 0.753mm in the Nuremberg 1 system. The two systems appear to be distinct.

iv) Karmarsch summarised

The small mistakes in the texts, the differences between the two systems for Nuremberg wire and the confusion of the half gauges imply that Karmarsch was perhaps not entirely at home with music wire and that we cannot rely on his descriptions of gauge systems as useful sources. Nonetheless, it is important here to note that Karmarsch applied the principle of the geometric progression in his approach to gauge systems. Not only did he compare the diameters of an existing system (used 'in Vienna') with a theoretical system based on a geometric progression but also, like Bleyer, he employed a geometric progression to calculate diameters for a system (Nuremberg 1) based on the thinnest and the thickest diameters and on the number of steps between. It is also significant that Karmarsch distinguished at least two different systems for sorting music wire, one used in conjunction with wire from Nuremberg, the other used 'in Vienna'.

Huber's 'Berlin' gauge system

By about 1820 the use of intermediate or 'half' gauges appears to have become established in Vienna. It also appears to have become the standard although not universal practice for builders to mark their instruments accordingly with a consistent set of whole and half gauges as follows:

...8/0, 8/0½, 7/0, 7/0½, 6/0, 6/0½, 5/0, 5/0½, 4/0, 4/0½, 3/0, 3/0½, 2/0, 2/0½, 1/0, 1/0½, 1, 1½, 2, ...

About twenty instruments, made between 1820 and 1835, with such gauges marked and with original strings have been found by Huber. He reports that the diameters of these strings, taken in conjunction with their corresponding gauge markings, conform to one and the same system. Huber calls this system the 'Berlin' system.[146]

146 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 202f. Huber gives very little exact data from the 'twenty or so' pianos.

i) The origin of the name 'Berlin' for Huber's system

Huber takes the name 'Berlin' from Rosamond Harding's book *The Piano-Forte*, where she gives diameters for each gauge of 'Berlin' wire.[147] Harding's source for these diameters is not clear although she gives references to 'Berlin' wire including texts by G. di Roma (1834) Claude Montal (1836) and Thon (1843). Harding does not clearly distinguish the terms 'Berlin wire', 'Berlin gauge Nos.' or 'Berlin wire gauge Nos.'.

Judging by Montal's table of concordance (see table 18), quoted by both Harding and Huber, Montal's Berlin gauge system is not the same as Huber's.[148] All the gauges in Huber's 'Berlin' system are thicker than in Thomée's Nuremberg system. But in Montal's table of concordance the larger Berlin gauges are thinner than their Nuremberg counterparts while the smaller Berlin gauges are thicker. Either Huber's 'Berlin' system is not the same as that of Montal, or Thomée's diameters for the Nuremberg system are not the same as those of Montal, or both. Knowing neither how Montal arrived at his table of concordance nor to which diameters he referred when making the table we are left in the dark.

147 Rosamond E. M. Harding, *The Piano-Forte. Its History traced to the Great Exhibition of 1851*, Cambridge 1978, 376-8.

148 Rosamond E. M. Harding, *The Piano-Forte. Its History traced to the Great Exhibition of 1851*, Cambridge 1978, 378, and Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 217. The original table is in Claude Montal, *L'Art d'accorder soi-même son piano*, Paris 1836, 71.

Montal's table of concordance between
a gauge systems for Nuremberg wire
and for Berlin wire

Nuremberg strings	Berlin strings
1/0	1
2/0	1/0
3/0	2/0
4/0	3/0
5/0	5/0
6/0	7/0
7/0	8/0
8/0	9/0
9/0	10/0
10/0	12/0
11/0	14/0
12/0	16/0

Table 18

Just as there appear to have been different systems for sorting Nuremberg wire so too there seem to have been different systems for Berlin wire. Huber quotes a list of diameters for Berlin wire, different from his own, given by Thomée in 1866. Not only are the diameters different but the use of half gauge markings is not the same. Thomée uses the same unconventional type given by Karmarsch in his Nuremberg 2 system (1833).[149] These are:

> $8/0\frac{1}{2}$, $8/0$, $7/0\frac{1}{2}$, $7/0$, $6/0\frac{1}{2}$, $6/0$, $5/0\frac{1}{2}$, $5/0$, $4/0\frac{1}{2}$,
> $3/0\frac{1}{2}$, $3/0$, $2/0\frac{1}{2}$, $2/0$, $1/0\frac{1}{2}$, $1/0$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$,...9

The gauge ratios for the 'Berlin' systems of Thomée and Huber are very close. Thomée's system has a gauge ratio of 1 : 1.098, while the gauge ratio in Huber's system is 1 : 1.118. But Thomée gives a diameter of 1.06mm for gauge 8/0 while Huber gives 1.30mm for the same gauge in his 'Berlin' system.[150] The two systems seem to be different.

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149 Claude Montal, in his *L'Art d'accorder soi-même son piano*, Paris 1836, 70, remarks on the peculiarity of having gauge $2/0\frac{1}{2}$ as the half gauge smaller than 2/0 rather than as the half gauge larger than 2/0 but emphasises that this is nevertheless the case with Berlin wire. Were Thomée and Karmarsch misinformed?

150 No instruments have yet been found with original strings and gauge markings which correspond to Thomée's Berlin system, to Montal's Berlin system or to Karmarsch's Nuremberg 2 system. For this reason it is hardly worthwhile examining the string thicknesses given by Thomée for Berlin wire in any more detail or to attempt a reconstruction of Montal's systems. Similarly, in the absence of absolute diameters, Thon's concordance of English numbers with Berlin gauge marks can offer little firm ground. Thomée's diameters for Berlin wire and Thon's concordance can be found in Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 213,214.

Confusingly, there thus appear to be at least four different Berlin systems, those of Harding, Montal, Thomée and Huber. The confusion surrounding Berlin wire and Berlin gauge systems is exacerbated by Huber's references to drawers of Berlin wire working in Vienna. Huber refers to Helmut Ottner's *Der Wiener Instrumentenbau* 1815-1833 where Johann Matthäus Di(e)tz is listed as a maker of '*Berliner Klaviersaiten*' (Berlin piano strings) in Vienna in 1833.[151] Huber then draws on Stephan von Keeß who had already mentioned Dietz in 1823. Keeß refers to Dietz as the best maker of strings in Vienna and that the city boasts

'5 to 6 similar wire drawers.'[152]

Huber implies that 'Berlin' wire was being drawn in Vienna by a number of manufacturers in 1823. Huber also appears to suggest that this 'Berlin' wire would have conformed to his 'Berlin' system even though there were at least four different Berlin systems.

One might speculate that the 'Berlin piano strings' made in Vienna by Dietz and others may simply have had the quality of the wire produced in Berlin rather than that they belonged to any Berlin gauge system. Berlin wire or wire of Berlin quality was not necessarily sorted according to a Berlin gauge system.

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151 Helmut Ottner, *Der Wiener Instrumentenbau* 1815-1833, Tutzing 1977, 36.

152 '[...] *5 bis 6 ähnliche Drahtzieher gezählt wurden.*' *Darstellung des Fabriks- und Gewerbswesens im Österreichischen Kaiserstaate. Vorzüglich in Technischer Beziehung*, Part II , ed. Stephan Edlem von Keeß, Vienna, 1823,484.

It is thus unfortunate that Huber adopted the name 'Berlin' for his system as this only adds to the considerable confusion surrounding both wire and systems referred to using the name Berlin. To remind the reader that Huber's 'Berlin' system may only have something vague to do with Berlin or indeed nothing to do with Berlin at all it is here referred to as the 'Berlin' system or Huber's 'Berlin' system with 'Berlin' in inverted commas.

ii) The diameters of the gauges in Huber's 'Berlin' system

The systematic use of intermediate or half gauges to fill out the number of steps within a wire gauge system, as illustrated in the system of Bleyer of 1811, came at a time when the theoretical idea that string diameters should follow a geometric progression was in the air. To quote Bleyer:

> 'The string thicknesses must increase and decrease in a geometric proportion if the tone of the instrument is to be even.'[153]

In the first decades of the nineteenth century a number of aspects of piano design, including stringing and scaling, began to take on the guise of rational enquiry as well as remaining matters of the

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153 '*Im geometrischem Verhältnisse müssen die Saiten-Dicken zu- und abnehmen, wenn die Töne des Instruments gleichförmig klingen sollen.*' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII*, Leipzig, November 1811, 74.

craftsman's tradition. The theoretical principle of the geometric progression was used to sort wire into gauge systems. It is therefore not surprising to find that the diameters given by Huber corresponding to his 'Berlin' system do more or less conform to a geometric progression. Table 19 gives the diameters of the gauges on an instrument by Conrad Graf as measured by Huber and which he gives as standard for his 'Berlin' system.[154] These are plotted logarithmically against gauge number in graph 6. A regression analysis of the successive whole gauges gives a gauge ratio of 1 : 1.118. The actual diameters are compared with their fitted diameters in table 20.

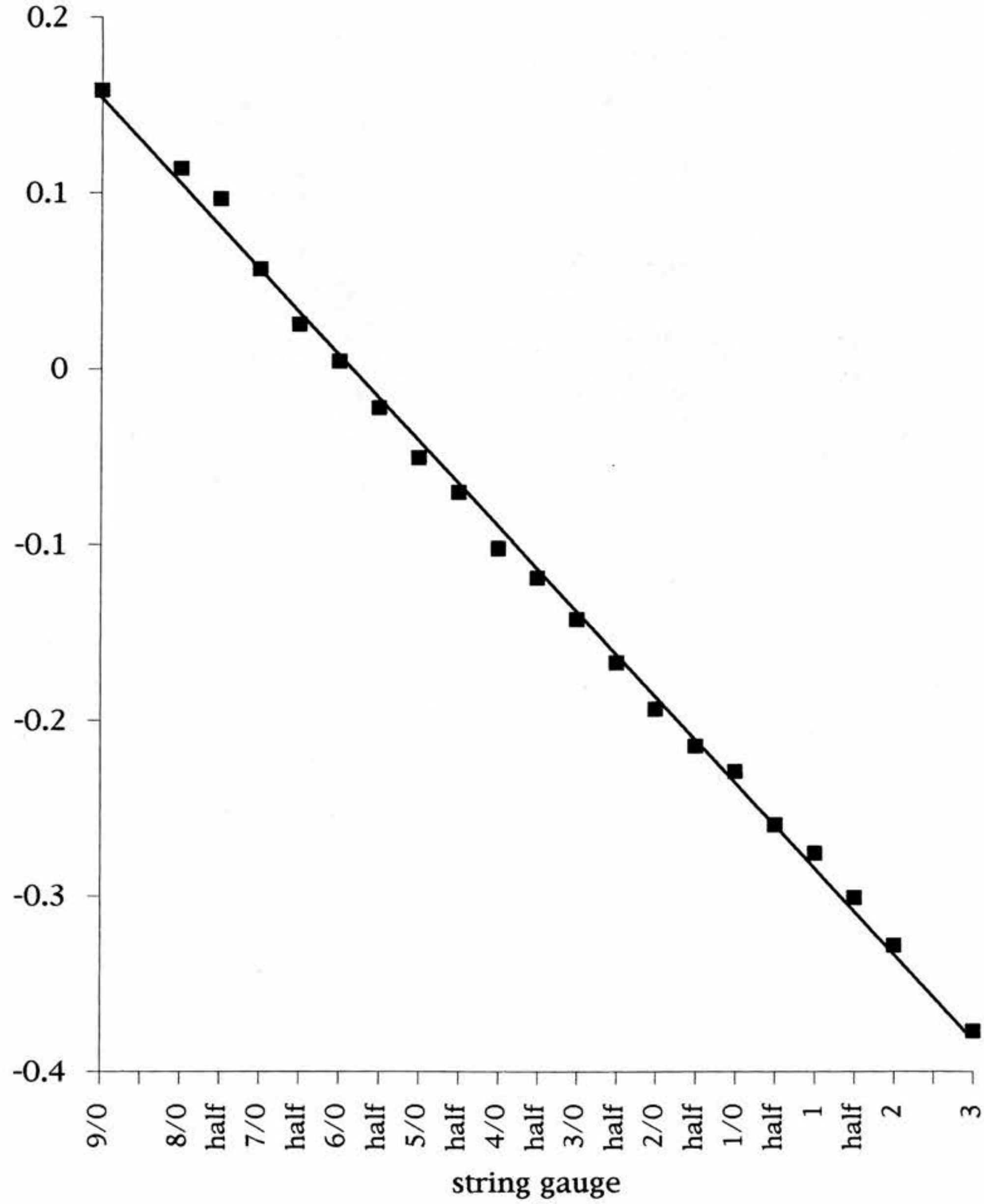
154 See Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 202f and 212 for the diameters of the 'Berlin' system.

Huber's 'Berlin' gauge system
diameters

Gauge	mm
9/0	1.44
8/0	1.30
8/0½	1.25
7/0	1.14
7/0½	1.06
6/0	1.01
6/0½	0.95
5/0	0.89
5/0½	0.85
4/0	0.79
4/0½	0.76
3/0	0.72
3/0½	0.68
2/0	0.64
2/0½	0.61
1/0	0.59
1/0½	0.55
1	0.53
1½	0.50
2	0.47
3	0.42

Table 19

Huber's 'Berlin' system
Diameters of strings on a piano by Conrad Graf
({c.1824/243}) plotted logarithmically against
gauge numbers



graph 6

Huber's 'Berlin' gauge system
diameters compared to the diameters fitted to a geometric progression

	Huber	fitted
Gauge	mm	mm
9/0	1.44	1.421
8/0	1.30	1.271
8/0½	1.25	1.202
7/0	1.14	1.136
7/0½	1.06	1.075
6/0	1.01	1.016
6/0½	0.95	0.961
5/0	0.89	0.909
5/0½	0.85	0.860
4/0	0.79	0.813
4/0½	0.76	0.769
3/0	0.72	0.727
3/0½	0.68	0.688
2/0	0.64	0.650
2/0½	0.61	0.615
1/0	0.59	0.582
1/0½	0.55	0.550
1	0.53	0.520
1½	0.50	0.492
2	0.47	0.465
3	0.42	0.416

Ratio between successive fitted whole gauge diameters 1 : 1.118

Ratio between successive fitted half gauge diameters 1 : 1.057

Table 20

iii) The evidence for the use of Huber's 'Berlin' system

The evidence for the use of Huber's 'Berlin' system remains the diameters of the strings found by Huber on some twenty instruments made between 1820 and 1835. Additional evidence is provided here by two instruments, one by Hofmann (H/c.1820) and one by Johann Fritz (F/7).

Using the usual criteria, many of the strings on the piano by Hofmann (H/c.1820) can be presumed original. Their diameters are given in table 21 and the average diameter for each gauge compared with Huber's 'Berlin' diameters. Taking into consideration that each gauge can comprise any diameters smaller than or equal to the size of that gauge but greater than the next gauge thinner the diameters for the brass strings conform to Huber's 'Berlin' diameters. The diameters of the iron strings, however, are close but mostly slightly larger than those given by Huber. This is illustrated in graph 7 where the average thicknesses of the strings on H/c.1820 are plotted logarithmically against gauge number.

In table 22 the average diameters of the strings on H/c.1820 and those (also presumed original) on a piano of about 1820 by Johann Fritz (F/7) are compared with the diameters of the strings on two pianos by Conrad Graf, one of about 1824, and the other of 1826, given by Huber as a standard for his 'Berlin' system.[155]

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155 {c.1824/423 and c.1826/609}. I am grateful to Alfons Huber for providing the information about the string gauges and the string

The two largest gauges on the piano by Fritz are not used by Graf or Hofmann, nor does Huber give diameters for them. From the logarithmic plot of the string diameters it can be seen that the diameters of the strings for these two gauges do not conform to the geometric progression followed by the others. We may therefore assume that the wire Fritz used for the two thickest gauges was not sorted according to Huber's 'Berlin' system.

thicknesses for both instruments by Graf (personal communication, September 1996).

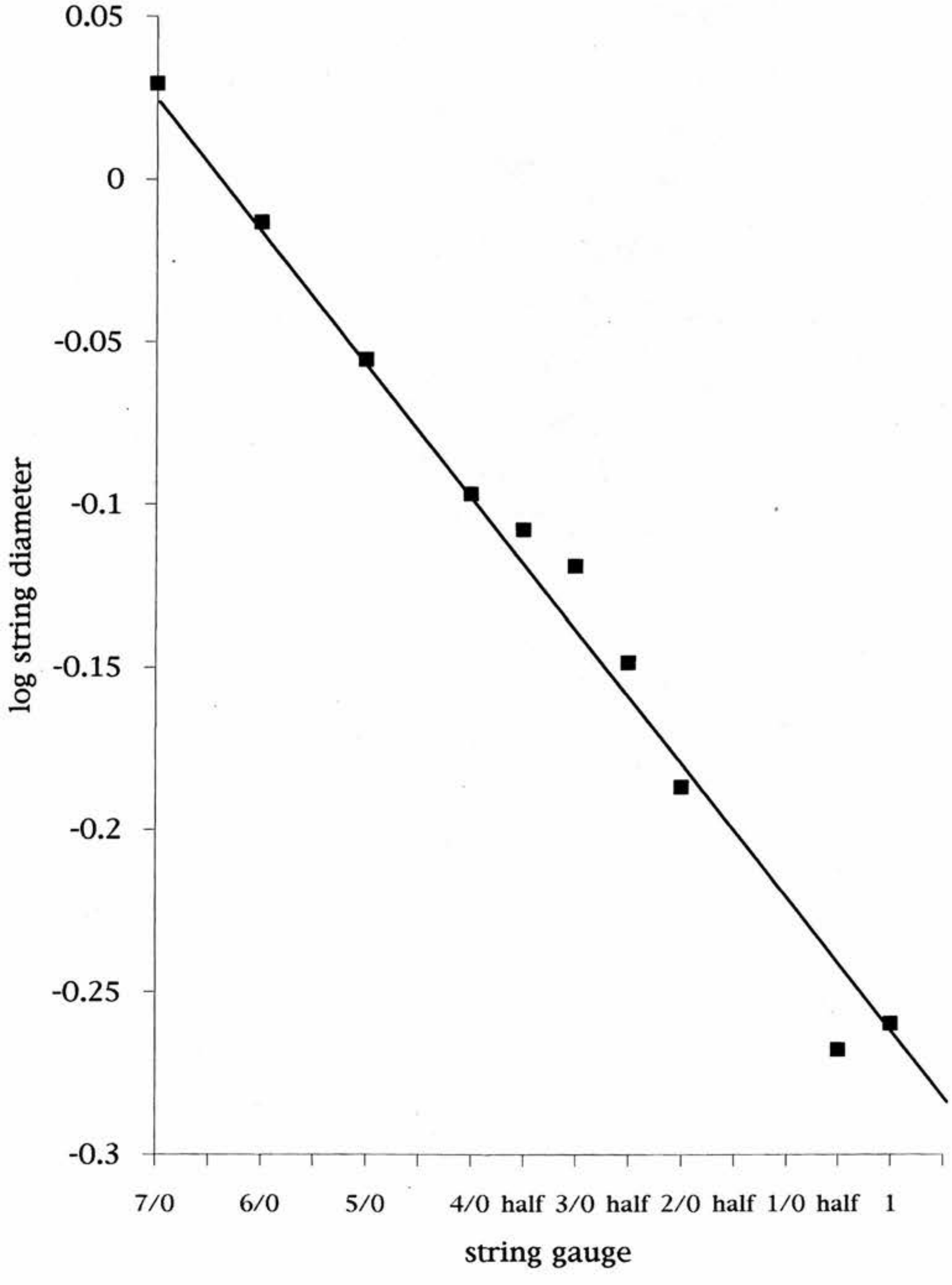
Diameters of the presumed original strings found on H/c.1820 compared with Huber's diameters for his 'Berlin' system

Note	Diameter	Diameter	Diameter	Average	Gauge marked	'Berlin' equivalent
	mm	mm	mm			mm
FF	1.09	1.07	1.07	1.07	7/0	1.14
FF#	1.07	1.05	1.05			
GG	0.96	0.96	0.96	0.97	6/0	1.01
GG#	0.96	0.99	n/o			
AA	n/o	n/o	0.99			
AA#	0.95	n/o	0.96			
HH	0.88	0.88	0.88	0.88	5/0	0.89
C	0.87	0.87	0.87			
C#	0.89	0.89	n/o			
D	n/o	0.80	0.81	0.80	4/0	0.79
D#	0.80	0.80	-			
E	0.81	0.80	0.80			
F	n/o	n/o	n/o			
F#	n/o	n/o	0.81	0.80	4/0	0.79
G	0.81	0.81	0.79			
G#	n/o	0.81	0.81			
A	0.80	0.81	0.78			
A#	0.78	0.78	n/o	0.78	4/0half	0.76
B	n/o	n/o	n/o			
c	0.77	n/o	n/o			
c#	n/o	0.79	-			
d	n/o	n/o	n/o	0.76	3/0	0.72
d#	0.76	0.77	0.76			
e	0.77	0.75	0.76			
f	0.75	0.76	0.75			
f#	n/o	n/o	n/o			
g	n/o	n/o	n/o	0.71	3/0half	0.68
g#	n/o	n/o	0.71			
a	0.72	0.72	0.72			
a#	0.69	0.68	0.71			
b	0.70	0.70	n/o			
c'	n/o	n/o	n/o			
c#'	n/o	-	-			
d'	-	n/o	n/o			

Note	Diameter	Diameter	Diameter	Average	Gauge marked	'Berlin' equivalent
	mm	mm	mm			mm
d#'	-	-	-	0.65	2/0	0.65
e'	0.65	0.64	-			
f'	-	-	-			
f#'	-	-	-			
g'	n/o	-	-			
g#'	-	-	-			
a'	-	-	-			
a#'	-	-	-			
b'	-	-	-	?	1/0	0.59
c"	-	-	-			
c#"	-	-	-			
d"	-	-	-			
d#"	-	-	-			
e"	-	-	-			
f"	n/o	-	-			
f#"	-	-	-			
g"	-	-	-			
g#"	-	-	-			
a"	-	-	-			
a#"	-	-	-	0.54	1/0half	0.55
b"	-	-	0.54			
c"'	0.54	-	-			
c#"'	-	-	-			
d"'	-	-	-			
d#"'	0.54	-	-			
e"'	-	-	0.55	0.55	1	0.53
f"'	-	0.55	0.55			
f#"'	-	-	0.54			
g"'	-	0.55	0.54			
g#"'	-	-	0.54			
a"'	0.57	0.55	-			
a#"'	0.56	0.55	0.54			
b"'	0.56	0.55	0.54			
c""	0.56	0.56	0.55			
c#""	0.55	0.54	-			
d""	0.55	0.55	0.56			
d#""	0.55	0.56	-			
e""	n/o	-	-			
f""	n/o	-	-			

Table 21

Logarithm of diameters (averages) of the strings found on H/c.1820 plotted against gauge numbers



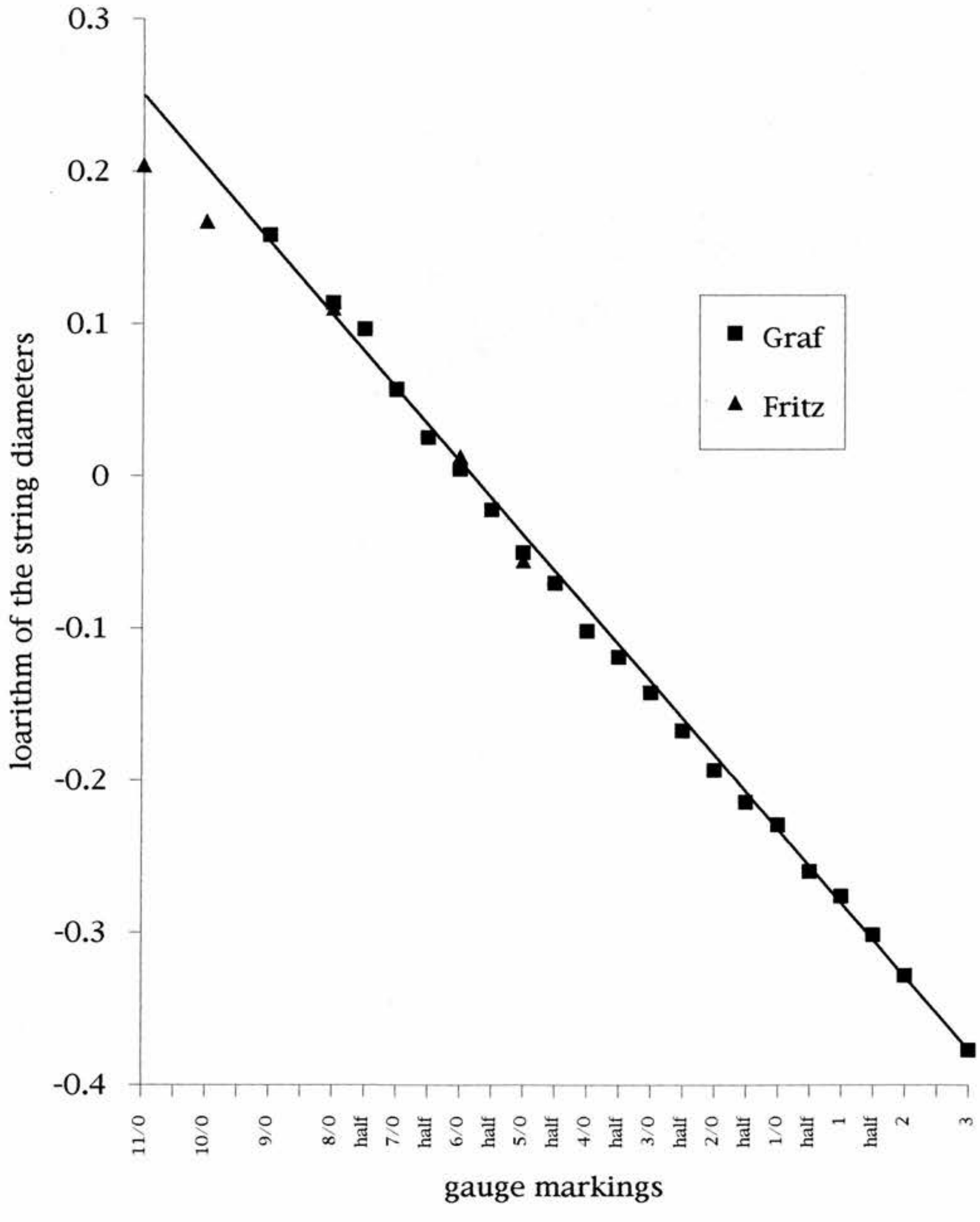
graph 7

Diameters of old wire on two pianos, one by Hofmann and one by Fritz compared with the diameters of the strings on two pianos by Graf (Huber's 'Berlin' system)

Maker	Hofmann	Fritz	Graf	Graf
Instrument	H/c.1820	F/7	c.1826/609	c.1824/423
Date	c.1820	c.1820	c.1826	c.1824
Gauge	mm	mm	mm	mm
11/0 brass	-	1.60	-	-
10/0	-	1.47	-	-
9/0	-	-	1.44	1.44
8/0	-	1.29	1.30	1.30
$8/0^{1}/_{2}$	-	-	1.25	1.25
7/0	1.07	1.14	1.14	1.15
$7/0^{1}/_{2}$	-	-	1.06	1.10
6/0	0.97	1.03	1.01	1.01
$6/0^{1}/_{2}$	-	-	0.95	0.95
5/0	0.88	0.88	0.89	0.90
$5/0^{1}/_{2}$	-	-	0.85	0.84
4/0 brass	0.80	-	0.79	-
5/0 iron	-	-	-	0.89
4/0	0.80	?	0.79	0.78
$4/0^{1}/_{2}$	0.78	?	0.76	0.76
3/0	0.76	?	0.72	0.72
$3/0^{1}/_{2}$	0.71	?	0.68	0.69
2/0	0.65	?	0.64	0.65
$2/0^{1}/_{2}$	?	?	0.61	0.61
1/0	?	?	0.59	0.58
$1/0^{1}/_{2}$	0.54	?	0.55	0.56
1	0.55	?	0.53	0.52
$1^{1}/_{2}$	-	-	0.50	-
2	-	-	0.47	-
3	-	-	0.42	-

Table 22

Logarithmic plot of the diameters of strings found on a piano by Johann Fritz (F/7, c.1820) and the diameters of the strings on a piano by Graf (c.1826, no. 609) taken as standard for Huber's 'Berlin' system



graph 8

iv) Huber's 'Berlin' system: conclusion

The various references to Berlin in the descriptions and analyses of music wire and string gauge systems are confusing. It is important to note however that the evidence for Huber's 'Berlin' system rests on the diameters of the strings, presumed original, found on a number of pianos built in Vienna between 1825 and 1830. There is no such evidence for any of the other 'Berlin' systems, those referred to by Harding, Montal and Thomée.

One further piece of indirect evidence for Huber's 'Berlin' system is Karmarsch's description of the system used 'in Vienna' published in both 1828 and 1833. The period between these dates is almost exactly the same as the period reported by Huber in which those pianos were made, also in Vienna, with strings conforming to his 'Berlin' system. Huber himself suggests that his 'Berlin' system, which has half gauge numbers, could be the same system as Karmarsch's system used 'in Vienna', which has no half gauge numbers.[156] This does indeed appear to be the case, as shown by a comparison of the gauge ratios of the two systems and of the respective diameters given for gauge 8/0. A regression analysis of the actual diameters of Karmarsch's system used 'in Vienna' gave a gauge ratio of 1 : 1.120, very close to the whole gauge ratio of Huber's 'Berlin' system, 1 : 1.118. Gauge 8/0 has a diameter of 1.316mm in Karmarsch's system and 1.30mm in

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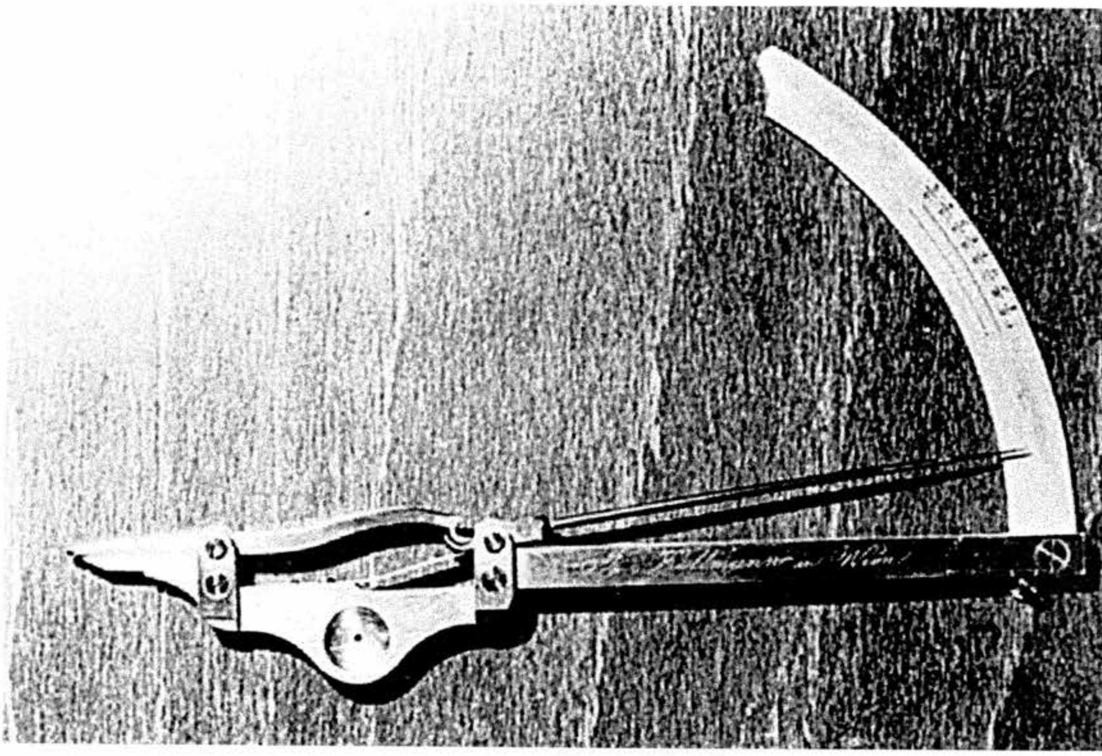
156 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 202 and 212.

Huber's 'Berlin' system. The two systems are thus the same except that Huber's system includes half gauges. This underlines the fact that the presence or absence of half gauges marked on an instrument cannot be used to determine the gauge system intended by the maker. Within a single gauge system half gauges were sometimes used and sometimes not.

The Vienna string gauge system

From about 1830 onwards the Streicher firm appears to have used yet another gauge system. Huber, who first presented the evidence for this system, calls it the Vienna system to distinguish it from the Nuremberg and 'Berlin' systems.[157] The diameters of the wire corresponding to the gauges of the Vienna system are defined by a gauge caliper used by the Streicher firm (ill. 14). Huber describes this gauge caliper, now in the Technical Museum in Vienna, in his article '*Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880*'. The caliper is calibrated for gauges no thicker than gauge 8/0 and no thinner than gauge 1, with half gauges marked between the whole gauges.

157 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 204.



ill. 14 The string gauge caliper used by the Streicher firm (Technisches Museum, Vienna)

i) The Vienna system compared with Huber's 'Berlin' system

The diameters for the Vienna system, as defined by the caliper and measured by Huber, are compared with the 'Berlin' system in table 23, together with the diameters of the strings, presumed original, on two instruments made by the Streicher firm 44 years apart, S/1837/2991 and S/1873/7383. The gauges of the Vienna system are each thicker than those of Huber's 'Berlin' system. The Vienna system and Huber's 'Berlin' system are plotted logarithmically in graph 9. As expected, the gauge diameters of the Vienna system follow a geometric progression.

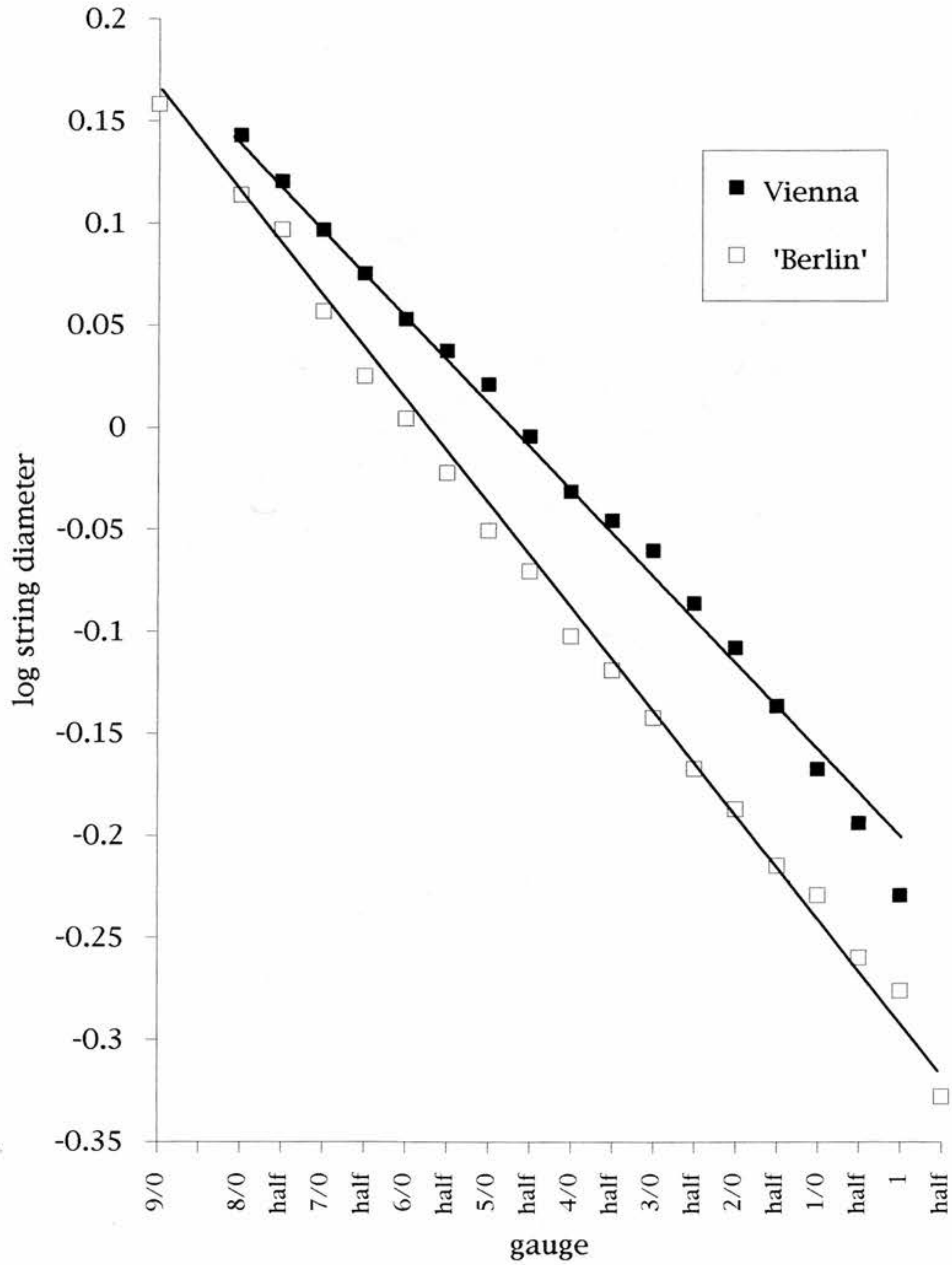
Table 24 presents the diameters given by the caliper fitted to a geometric progression. The whole gauge ratio for the Vienna system is 1 : 1.108, very close to the whole gauge ratio in Huber's 'Berlin' system, 1 : 1.118. The diameter for gauge 8/0 of 1.39mm in the Vienna system is only somewhat larger than in Huber's 'Berlin' system (1.30mm). The similarity of the gauge ratios and of the diameter of gauge 8/0 suggests that these two 'systems' could be one and the same.

The diameters of strings on two pianos of the Streicher firm (1837 and 1873) compared with Huber's 'Berlin' gauge system and the Vienna system defined by the Streicher caliper (all mm)

Gauge	'Berlin'	Vienna		
		caliper	S/1837/ 2991	S/1873/ 7383
12/0	-	-	2.05	-
11/0	-	-	1.85	-
10/0	-	-	1.65	-
9/0	-	-	1.50	-
8/0	1.30	1.39	1.40	-
8/0 1/2	1.25	1.32	1.35	-
7/0	1.14	1.25	1.25	1.25
7/0 1/2	1.06	1.19	1.20	1.20
6/0	1.01	1.13	1.15	1.12
6/0 1/2	0.95	1.09	1.05	1.05
5/0	0.89	1.05	1.00	0.99
5/0 1/2	0.85	0.99	0.95	0.96
4/0	0.79	0.93	0.93	0.92
4/0 1/2	0.76	0.90	0.90	0.89
3/0	0.72	0.87	0.85	0.87
3/0 1/2	0.68	0.82	0.80	0.82
2/0	0.64	0.78	0.75	0.79
2/0 1/2	0.61	0.73	0.73	0.74
1/0	0.59	0.68	0.70	-
1/0 1/2	0.55	0.64	0.65	-
1	0.53	0.59	-	-
1/2	0.50	-	-	-

Table 23

Logarithm of the Vienna string diameters
(Streicher's gauge caliper) and Huber's 'Berlin'
system plotted against gauge numbers



graph 9

The diameters of the Vienna system,
defined by the Streicher caliper,
fitted to a geometric progression

Gauge	measured diameter (mm)	fitted diameter (mm)
8/0	1.39	1.402
8/0$^1/_2$	1.32	1.333
7/0	1.25	1.267
7/0$^1/_2$	1.19	1.204
6/0	1.13	1.144
6/0$^1/_2$	1.09	1.087
5/0	1.05	1.033
5/0$/_2$	0.99	0.981
4/0	0.93	0.933
4/0$^1/_2$	0.90	0.885
3/0	0.87	0.842
3/0$^1/_2$	0.82	0.800
2/0	0.78	0.760
2/0$^1/_2$	0.73	0.722
1/0	0.68	0.687
1/0$^1/_2$	0.64	0.652
1	0.59	0.620

Ratio between successive fitted whole gauge diameters 1 : 1.108

Ratio between successive fitted half gauge diameters 1 : 1.053

Table 24

ii) The date of the caliper

The date of the caliper, which gives a date by which the Streicher firm was using the Vienna system, is a matter of discussion. Huber argues that the caliper dates from about 1825 because gauge 1 was not used by the Streicher firm after about 1825 and because the thinnest size for which the gauge caliper is calibrated is gauge 1. But one piano by Streicher of 1827 has gauge 2 marked in the extreme treble and, more importantly, four pianos of between 1832 and 1839 are marked for gauges 12/0, 11/0, 10/0 and 9/0 in the bass. These gauges are all thicker than the thickest size, gauge 8/0, which can be measured by the caliper.[158] Huber himself also gives diameters of strings found on a piano by Streicher of 1835 with gauge markings starting with gauge 12/0 and ending with gauge 3, exceeding the measurement range of the caliper for both its thickest and thinnest gauges.

The earliest instruments made by the Streicher firm to which the caliper is suited were made in 1839. In these pianos (not those with a down-striking action) there were covered strings for the notes CC to EE and no gauges were marked for them.[159] The gauge markings begin with 8/0 at FF and continue up in whole and half gauges to gauge $1^{1}/_{2}$.

More evidence for a later date than 1825 for the caliper is

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158 S/1827/2185 has gauge 2 marked and S/1832/2548, S/1835/2750, S1837/2991 and S/1839/3304 have the thicker gauges marked.

159 For instance S/1839/3304, S/1839/3261 and S/1839/3338.

provided by the general lack of consistent half-gauge markings on the pianos made between 1811 and 1830. Apart from whole number gauges, the gauges marked on S/1811/908, S/1816/1117 and S/1819/1415 only include gauge $1/0^{1}/_{2}$ and the pianos of between 1820 and 1830 only include gauges $3/0^{1}/_{2}$ and $2/0^{1}/_{2}$, with the exception of S/1828/2237 which also has gauge $4/0^{1}/_{2}$.

Only from 1839 onwards are all the gauges measured by the caliper, and only those gauges, marked on pianos by the Streicher firm. Taking only the evidence of the gauge markings on the pianos, it is thus more likely that the Streicher gauge caliper dates from about 1839 rather than from 1825.

S/1837/2991, however, was made before the date of 1839, proposed here for the caliper, and still retains strings that closely conform in thicknesses to the Vienna sizes defined by the caliper. This could either be because the piano was later re-strung with the Vienna sizes or because the caliper only came into use some time after Streicher started with the Vienna system. The latter explanation appears to be the most plausible in the light of the fact that the diameters of the hammer return springs of a down-striking piano made by the Streicher firm in 1826 closely conform to the Vienna system.[160] The gauges are marked for these springs, and taken together with the diameters of the brass wire used for the springs, provide eveidence for the use of the Vienna system already in 1826.

160 The springs (brass) of S/1826/2053. See Malcolm Rose and David Law, *A handbook of Historical Stringing Practice for Keyboard Instruments*, Lewes and Long Compton 1991, 128.

The date of the caliper, even if it were known with certainty, cannot be used as evidence for the date at which the Streicher firm began to use the Vienna system. On the other hand, we do know that the Streicher firm was using the gauge system defined by the caliper, the Vienna system, by 1839, the date at which the caliper probably came into use.

The use of different gauge systems by the Streicher firm

The following observations are based on those instruments by the Streicher firm which have gauge markings. These are stamped or written on the wrestplank or, in the special cases of some of the down-striking pianos, next to the return springs for the hammers. A number of the surviving pianos by Nannette Streicher made between 1802 and 1820 either never had string gauge markings or have lost them.

Two pianos by Nannette Streicher, S/c.1804b and S/1807/733, still have strings of diameters which fit Thomée's interpretation of the Nuremberg system. The uniformity of the stringing schemes on S/1807/733 and on S/1811/902 indicate that the Streicher firm used this system until 1811. In 1819, or possibly earlier, the firm may have used the Streicher 1819 system, a system which can be differentiated from both the Nuremberg system and Huber's 'Berlin' system. It should however be emphasized that the evidence for the Streicher system comes from the strings of only one instrument, S/1819/1415.

There is some tenuous evidence for Streicher's use of a Berlin system in Gustav Schilling's '*Encyclopädie*', volume 1, published in 1835. There, in the article dealing with the leathering of piano hammers, Schilling discusses the relation between the number of layers of leather on hammer heads and the thicknesses of the strings. In comparing different instruments he states:

> 'We are judging here from the well-known Berlin strings, and from the policy of the most famous masters at present, Graff [*sic*] in Vienna, Rittmüller in Göttingen, Schiedmaier [*sic*] in Stuttgart, and Streicher in Vienna.'[161]

The problems of Berlin wire and Berlin systems were discussed above. It is sufficient to note here that there is no way of knowing exactly what the words 'well-known Berlin strings' mean. The most plausible explanation is that the strings either came from Berlin or were of the quality of the wire made in Berlin. There is no reason why a sorting system should be 'well-known' but every reason why wire of good quality would acquire a good reputation.

The Streicher firm probably used the Vienna system from as early as 1826, judging from the hammer return springs of S/1826/2053, and until as late as 1873 or later. But one must not forget that at any one time they (and indeed any firm) did not necessarily use either one system or one type of wire to the exclusion of others. The gauge marks stamped on the wrestplank of

161 Schilling, ed., *Encyclopädie*, I, 1835, 537, art. '*Beledern*': '*Wir urtheilen hier nach den bekannsten Berliner Saiten, und nach dem Verfahren der jetzt berühmtesten Meister, Graff in Wien, Rittmüller in Göttingen, Scheidmaier in Stuttgart, und Streicher in Wien.*'

some pianos by the Streicher firm are those used for the so-called English patent steel and follow the Birmingham music wire system. In this gauge system, quite different to the continental systems, a low number, such as 6, indicates a thin gauge while a high number, such as 28, a thick gauge. The oldest surviving example of a piano by Streicher with such gauge marks, in private ownership in Austria, carries the production number 3739 and the date 1847.

String gauge systems - summary

We can assume that after about 1800 wire was available in Vienna which not only came from Nuremberg but also from elsewhere, including Vienna.[162] This wire varied in quality, a fact to which Thon alluded in 1817.

> 'If the strings have been drawn down too heavily and are thereby hardened too much and the coils do not hold but repeatedly jump off, one either anneals the end of the same or, what is always more advantageous, takes a roll of wire of better material, which is also easier to tune and bring up to the required pitch.[163]

162 According to Ignaz de Jura in *Österreichisches Staatenkunde im Grundrisse*, Wien, 1786-1789, III, 383, there were no local wire drawers in Vienna before 1788 '[...] *eine eigene Fabrik dieser Art bestehet bis jetzt in den Erblanden nicht. Demjenigen, welcher sich zur Fabricatur guter musikalische Drahtsaiten fähig hält werden Belohnungen zugesichert.*'

163 '*In dem Falle die Saiten zu stark gezogen, mithin zu sehr gehärtet sind und die Schlingen nicht halten wollen, sondern mehrmals abspringen: so glüht man das Ende derselben entweder gelinde aus, oder nimmt, welches stets zuträglicher ist, eine Saitenrolle von bessern Stoffe, die sich auch leichter stimmen und zu der erforderlichen Höhe hinauf treiben läßt.*' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden*

Early in the nineteenth century there also appears to have been a variety of concurrent gauge systems. The plurality of systems combined with the plurality of sources lead to confusion. Two sources, one of 1817 and one of 1823 make the point abundantly clear. In 1817 Thon wrote:

> 'Many instruments have the gauges marked on them by the builder, others not. Although cases of the latter sort are not rare this involves no disadvantage because the gauge numbers in the various wire factories and brass foundries are not equal; one and the same gauge is sometimes thicker, sometimes thinner depending on the extent to which the widths of the apertures in the drawing dies vary. To be most certain of keeping to the stringing scheme laid down by the builder, therefore, one should be given a string measuring tool, either from the factory where the strings were made or one made according to the stringing [of the instrument]. One can even select the strings using a sharp and practised eye. This is practically always better than just using the gauge markings.'[164]

Besitzer dieser Art Metallsaiteninstrumente, Sondershausen 1817, 111.

164 '*Bei manchen Instrumenten sind von dem Baumeister die Nummern bemerkt, bei andern aber nicht, und obgleich diser letzte Fall nicht selten statt findet; so ist eben damit kein Nachtheil verbunden, weil die Nummern in den verschiedenen Saitenfabriken und Messingwerstätten sich doch nicht gleich sind und eine und dieselben bald stärker, bald schwächer gefunden werden, ienachdem die Zieheisen in der Weite ihrer Löcher gegenseitig von einander abweichen. Am sichersten wird daher das, von dem Baumeister des Instruments zum Grund gelegte, Nummerschema beibehalten, wenn entweder die Fabrik, aus welcher die Saiten bezogen sind, an- oder ein nach dem Saitenbezug eingerichtetes Chordometer beigegeben wird. Schon ist ein geübtes und scharfes Gesicht im Stande, die Saiten durch das Augenmaaß auszuwählen, welches fast immer richtiger, als die bloße Angabe der Nummern, leiten wird.*' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 88. Similar remarks are found in Gall, Vienna 1805, 69-74, copying Nachersberg, Breslau und Leipzig 1804, 121-6.

In 1823 Stephan Edlem von Keeß wrote:

> '...and so one can assume as a rule that amongst 12 wire manufacturers there are hardly 2 who make all sizes according to the same gauge system [*Lehre*], i.e. each gauge according to the same thickness.'[165]

The difficulties of interpreting gauge markings are exacerbated by the confusion surrounding the sources and types of wire, the systems into which wire was sorted and the names wire was given. Nuremberg wire does not always imply the use of the Nuremberg system while Berlin wire was made in Vienna.

The presence or absence of gauge markings for half sizes is not in itself sufficient grounds for identifying a particular gauge system, as is sometimes thought. In theory, any system could include half gauges; in practice half gauges appear to have been included in every system, sometimes sporadically, sometimes systematically.

Bearing these problems in mind, any interpretation of the gauge markings found on a particular instrument should be regarded with caution, especially in the period between about 1810 and 1835 when confusion was particularly rife. Re-stringing

165 '*Doch verfertigen nicht alle Fabrikanten die gleichen Sorten, und selbst bey gleicher Benennung ist der Draht aus verschiedenen Fabriken nicht gleich....und so kann man als Regel annehmen, daß unter 12 Drahtfabriken kaum 2 find, welche alle Sorten nach gleicher Lehre, d. i. nach gleiche Stärke oder Dicke verfertigen.*' *Darstellung des Fabriks- und Gewerbswesens im Österreichischen Kaiserstaate. Vorzüglich in Technischer Beziehung*, Zweyter Theil , ed. Stephan Edlem von Keeß, Vienna, 1823, 567. The author would like to thank Alfons Huber for bringing this source to his attention.

a piano according to an interpretation of a set of gauge markings can be disastrous if the diameters chosen for each gauge are too thick and futile if they are too thin.

The sparse evidence suggests that the Nuremberg system, as reported by Thomée, was used in Vienna until 1811 and probably later. Bleyer advertised his own system in 1811 as an improvement on the Nuremberg system. He appears to have used his system in a surviving instrument of about 1815. Huber has distinguished another system, his 'Berlin' system, from Thomée's Nuremberg system and has found some twenty instruments with strings as evidence for this system in the period between 1820 and 1830. That this 'Berlin' system can be distinguished from the Nuremberg system because the former includes half gauges while the latter does not cannot be sustained. Huber's 'Berlin' system differs from the Nuremberg system only in that the 'Berlin' system has slightly larger diameters for each respective gauge.

On the thin evidence of a single instrument it can be suggested that the Streicher firm used another system (the Streicher 1819 system) around 1819. After about 1835 the Streicher firm used a caliper which indicates a system similar to Huber's 'Berlin' system but again with larger diameters for each gauge. Huber calls this system the Vienna system. It was probably used by the Streicher firm from 1826 to at least 1870 although not to the exclusion of other systems. In 1828 and 1833 Karmarsch reported three different systems, one of which appears to be the same as Huber's 'Berlin' system. No instruments survive with old strings to provide evidence for Karmarsch's other two systems.

The evidence for the various systems is extremely thin. There are perhaps no more than half a dozen instruments providing evidence of the Nuremberg system as reported by Thomée and twenty-five providing evidence of Huber's 'Berlin' system. By 1830 there were some 300 piano makers working in Vienna producing literally thousands of pianos a year so that the remaining instruments with old strings and gauge markings provide only a small (if precious) sample.

Bleyer used a geometric progression to calibrate his gauge measuring device, that is, as a starting point for constructing a gauge sorting system and Karmarsch appears to have assumed that the diameters of current string gauges (those used 'in Vienna') would approximate to a geometric progression. Karmarsch also assumed a geometric progression when calculating the diameters of a known number of gauges between two extreme gauges. Working at the beginning of the nineteenth century both Bleyer and Karmarsch used the geometric progression as an *a priori* mathematical principle, as a starting point for constructing and analysing gauge systems. In contrast, if the Nuremberg gauge system was originally based on a geometric progression this was probably not because of the application of an *a priori* principle but the result of the underlying principles of wire drawing.

That we can expect the series of diameters of each gauge system to approximate to a geometric progression gives us a useful tool for comparing the different systems. In table 25 the ratio between diameters for successive whole gauges, fitted to geometric progression, is given for each system. The fitted diameter of gauge

8/0, where known or where it can be calculated is also given. It is assumed that Karmarsch intended 15 gauges for his system for Nuremberg wire and that Bleyer's system should be treated as if it were a half gauge system even though it only includes whole gauge numbers. For Bleyer's system, therefore, every other gauge is taken as equivalent to a whole gauge in the other systems. In all systems with half gauges the ratio between the diameters of successive half gauges is also given. To distinguish them from the others, these entries are given in italics. The gauge ratios are designated r_g following Grant O'Brien.[166] O'Brien further designates the 'drawing ratio' r_d (= r_g^2). This value indicates the ratio between the length of a given volume of wire before and after drawing, assuming that each successive draw is given a new gauge number. It should be remembered, however, that there is no necessary connection between the drawing ratio and the gauge ratio, certainly in the nineteenth century. The wire was probably drawn in a continuous series of diameters and sorted afterwards according to a geometric progression.

166 See Grant O'Brien, 'Stringing Materials and Gauges for Clavichords by I. C. Gerlach and H. A. and J. A. Hass', *De Clavicordio, Proceedings of the International Clavichord Symposium*, Magnano 1993, 129.

Chronological comparison of the various gauge systems

(Half gauge systems given in italics)

System	Date	r_g	r_d	gauge 8/0 fitted (mm)	gauge 8/0 actual (mm)
Nuremberg (Thomée 1866)	to c. 1815	1.111	1.234	1.152	1.06
Bleyer (as 17 half gauges)	*1811*	*1.044*	*1.091*	*?*	*?*
Bleyer (9 whole gauges)	1811	1.091	1.189	?	?
Brodmann ({Wörlitz})	1818	-	-	-	1.15
Streicher 1819	1819	1.159	1.343	1.350	1.30
'Berlin' (half gauges)	*1820-1835*	*1.057*	*1.118*	*1.271*	*1.30*
'Berlin' (whole gauges)	1820-1835	1.118	1.250	1.271	1.30
Karmarsch (Nuremberg 1)	1828	1.126	1.268	1.210	-
Karmarsch ('in Vienna')	1828, 1833	1.120	1.254	1.315	-
Karmarsch (Nuremberg 2)	*1833*	*1.051*	*1.104*	*0.885*	-
Karmarsch (Nuremberg 2)	1833	1.104	1.219	0.885	-
Thomée Berlin (half gauges)	*?*	*1.048*	*1.098*	*1.124*	*1.06*
Thomée Berlin (whole gauges)	?	1.098	1.206	1.124	1.06
Vienna (Streicher caliper) (17 half gauges)	*c.1826-70*	*1.053*	*1.108*	*1.402*	*1.39*
Vienna (Streicher caliper) (9 whole gauges)	c.1826-70	1.108	1.228	1.402	1.39

Table 25

The gauge ratio of the Nuremberg system, 1 : 1.111, could have simply been derived from a drawing ratio of 1 : 1.111 as follows. Take a length of wire of gauge 9/0 which is $4^1/_2$ units long and draw it down such that it becomes 5 units long. The drawing ratio is then $4^1/_2$: 5 or 1 : 1.111. Repeat this process using the same drawing ratio and take the wire thus produced (by two consecutive draws) as the next gauge thinner, gauge 8/0. The combined drawing ratio of the two successive draws is then $(1 : 1.111)^2$. Because the gauge ratio is equal to the square root of the drawing ratio the gauge ratio between gauges 9/0 and 8/0 will be $\sqrt{(1 : 1.111)^2}$ which, of course, is 1 : 1.111. In other words, by taking every alternate draw as the next gauge thinner the drawing ratio for each single draw becomes the same as the gauge ratio, equivalent in this case to $4^1/_2$: 5. Such ratios, employing halves, were indeed used. Karmarsch mentions that

> 'The wire drawer knows from experience that he must choose the size of the drawing die according to circumstances, that the increase in length should be $2^1/_2$, 3, $3^1/_2$ or 4 units.'[167]

O'Brien refers to the simple drawing ratio of 4 : 5 as 'expected'. This is based on the assumption that a drawing ratio of 4 : 5 was consistently used and that every draw was assigned a

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167 *'Der Drahtzieher weiß aus Erfahrung, daß er nach Umständen die Größe der Ziehlöcher so zu wählen hat, daß die Verlängerung $2^1/_2$, 3, $3^1/_2$ or 4 Zängel betragen muß.'* From Karl Karmarsch's article *'Draht'* in Johann Joseph Prechtl, *Technologische Enzyklopädie oder alphabetisches Handbuch der Technologie* ..., vol. 4, Stuttgart 1833, 226.

new gauge. In the Nuremberg system this does not seem to be the case. It appears that the drawing ratio used was $4^{1}/_{2}$: 5 and that only every second draw was assigned a new gauge.

If, however, Thomée's diameters for the Nuremberg system are respected, it must be admitted that the Nuremberg system as a whole does not follow a geometric progression, a fact for which we have no immediate explanation. It may have been the dissatisfaction of having gauges with diameters which did not follow a geometric progression which led Bleyer to rationalise the Nuremberg system by establishing a constant gauge ratio.

String gauge systems - conclusion

The interpolation of half gauges does not of itself define a new system. In the nineteenth century the drawing ratio bore no necessary relation to the gauge ratio. On the basis of these two conclusions table 25 has been simplified in table 26 to compare the different gauge systems according to their gauge ratios using only the whole gauge versions and omitting the drawing ratios. To show the rate of change of diameter the fitted diameters for gauges 8/0 and 4/0 are given.

Of particular interest is the similarity between Thomée's Berlin system and his Nuremberg system. Thomée's Berlin system, which has half gauges and more or less follows a geometric progression, may simply be an interpolated and rationalised version of his Nuremberg system, which has no half gauges and does not follow a geometric progression. In this sense Thomée's Berlin system appears to be the same as Bleyer's system. Both are rationalisations of the Nuremberg system. The difference between the two lies only in the names given to the sizes. Thomée used half numbers between the whole numbers while Bleyer, to avoid 'the confusion' of half gauges gave the same set of diameters whole number names only. The system is the same, only the nomenclature is different.

Comparison of the various gauge systems
given in order of gauge ratio

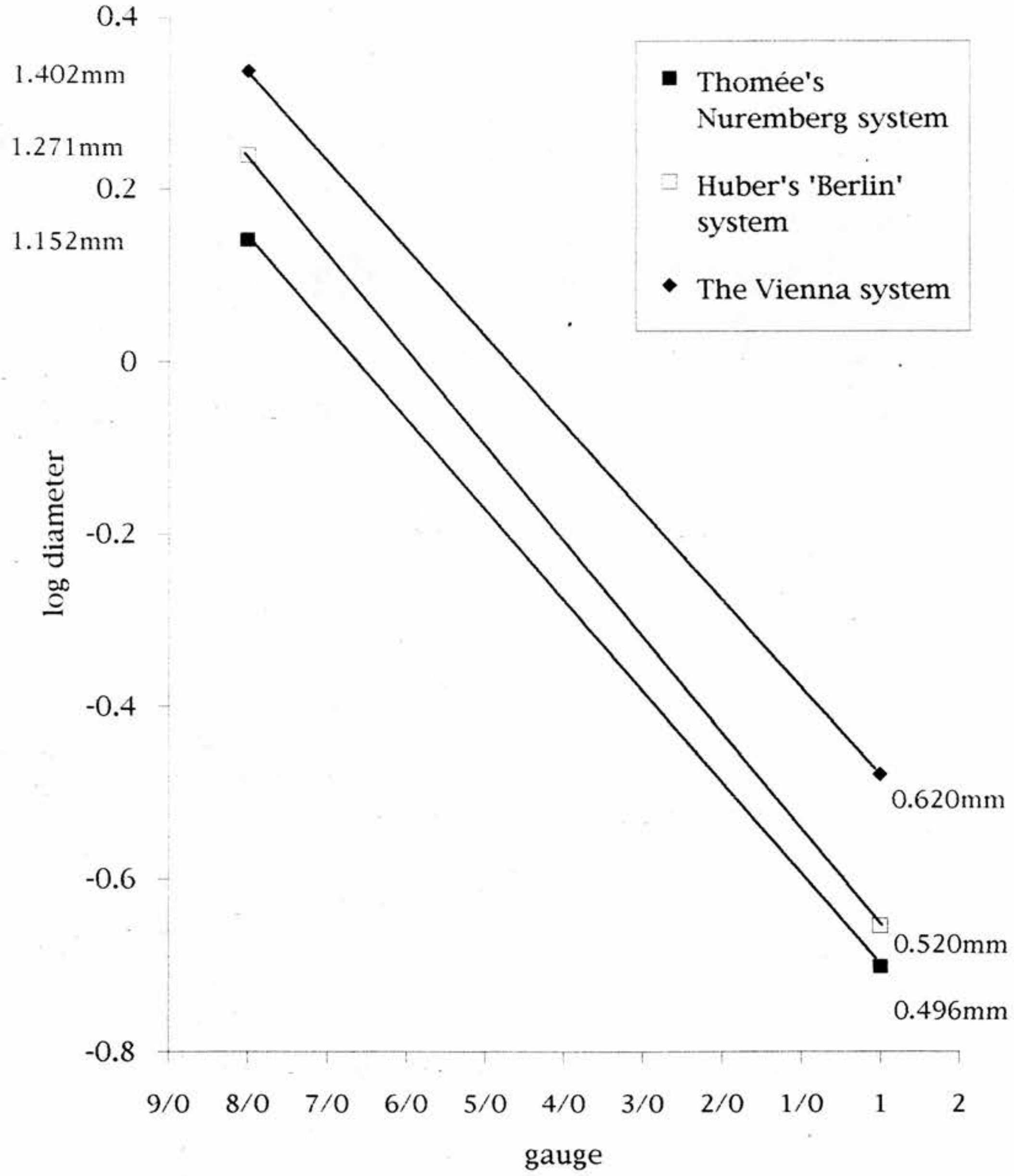
System	Date	gauge ratio	gauge 8/0 fitted (mm)	gauge 4/0 fitted (mm)	gauge 8/0 actual (mm)
Bleyer	1811	1.091	?	?	?
Berlin (Thomée 1866)	?	1.098	1.124	0.773	1.06
Karmarsch (Nuremberg 2)	1833	1.104	0.885	0.596	-
Vienna (Streicher caliper)	c.1826	1.108	1.402	0.933	1.39
Nuremberg (Thomée 1866)	to c.1815	1.111	1.152	0.756	1.06
'Berlin' (Huber)	1820-1835	1.118	1.271	0.813	1.30
Karmarsch ('in Vienna')	1828, 1833	1.120	1.315	0.836	-
Karmarsch (Nuremberg 1)	1828	1.126	1.210	0.753	-
Streicher 1819	1819	1.159	1.350	0.749	1.30

Table 26

There are only three systems for which we have concrete evidence. These are Thomée's Nuremberg system, Huber's 'Berlin' system and the Vienna system. Nowhere, except in the modern literature, which includes Thomée's report, are any of these systems mentioned by name. Only the wire is given a name, referring either to its origin or its quality. Not only is the evidence for each of the three systems sparse but there is no evidence in the contemporary literature that they were distinguished as different systems at all. The gauge ratios of the three systems are not very different from each other (1 : 1.108, 1 : 1.111 and 1 : 1.118). By taking this into account and by imagining that the traditional diameter for each nominal gauge gradually increased with time one could speculate that these three systems are simply all the same system, certainly if one considers the fitted diameters rather than the actual diameters. This is illustrated in graph 10.

From the point of view of at least some piano builders there may not have been a plurality of systems but simply piano wire, sold in nominal gauges. Intermediate or half gauges could also be obtained around 1800 and became standard by about 1825. It is tempting to suggest that in principle the wire drawers maintained a traditional drawing ratio of 1 : 1.111, as they had always done, assigning every alternate draw a new whole gauge number. If they or their customers required half sizes the appropriate intervening draws would also be selected and assigned half gauge numbers.

Comparison of the gauge ratios and of the diameters for gauges 8/0 and 1 fitted to a geometric progression for Thomée's Nuremberg system, Huber's 'Berlin' system and the Vienna system



graph 10

If the hypothesis of a single system is true the strings on the five pianos by Hofmann which are too thick to fit Thomée's list of diameters for the Nuremberg system could still be considered to be the original strings but obtained from a wire drawer already drawing thicker diameters for each gauge. Similarly, the diameters of the strings found on the piano by Brodmann of 1818 which fit neither Thomée's diameters for the Nuremberg system nor Huber's diameters for his 'Berlin' system may simply have been drawn by a wire drawer who did not sort his gauges accurately according to a geometric progression. Even the Streicher 1819 'system' may be considered as a variant of the same 'single system'. The two gauges in the bass of the piano by Fritz (F/7) which did not conform to Huber's 'Berlin' system may have been obtained from a different wire drawer to the one who supplied the other gauges.

Another instrument with presumed original strings of which the diameters, taken in conjunction with their gauge markings, conform neither to Thomée's Nuremberg system nor to Huber's 'Berlin' system, is a piano of about 1817 inscribed *Anton Walter und Sohn* (W/c.1817). The diameters of the strings on this instrument are given in table 27.

The diameters of the strings on two of the pianos by Hofmann (H/1785a and H/1795c), the piano by Brodmann of 1818 ({Wörlitz}), the diameters of the Streicher 1819 system (S/1819/1415) and the diameters of the strings of the piano by Walter und Sohn (W/c.1817), in each case averaged for each gauge, are compared in table 28 with the diameters both of Thomée's Nuremberg system and of Huber's 'Berlin' system. The table shows that none of these instruments appears to have been strung according to either 'system'.

Let us assume that Thomée's Nuremberg 'system' developed over time in such a way that each nominal gauge designated wire of an increasingly thicker diameter. Let us also assume that Huber's 'Berlin' 'system' is one stage in that development. We can then understand the two 'systems' as one and the same. The diameters of the strings found on each of the pianos in table 28 then fall into place within that single system, a system of nominal gauge numbers for string sizes which, in practice, varied in diameter but which also tended to increase in diameter with time.

A piano by Walter und Sohn (W/c.1817)
String diameters as measured

note name	ø mm	ø mm	ø mm	gauge average	gauge marking	note name	ø mm	ø mm	ø mm	gauge average	gauge marking
FF	0.95	0.95	0.95	0.95	6/0	gap-spacer	0.52	0.53			
FF#	0.95	0.94	0.95			f#'	0.55	0.55	0.54		(1/0)
GG	0.95	0.96	0.96			g'	0.54	0.53	0.54		
GG#	0.89	0.87	0.87	0.87	5/0	g#'	0.53	0.54	0.53		
AA	0.87	0.87	0.88			a'					
AA#	0.88		0.88			a#'					
BB	0.87		0.87			b'			0.53		
C	0.79	0.79	0.79	0.79	4/0	c''					
C#	0.79	0.79	0.80			c#''	0.54	0.54	0.54		
D	0.81	0.80	0.81			d''					
D#	0.81					d#''	0.53	0.54	0.53		
E	0.79	0.78	0.80		4/0	e''					
F	0.79	0.80	0.80			f''		0.52			
F#	0.81	0.79				f#''	0.48	0.49	0.48	0.48	1
G	0.80	0.78	0.78			g''					
G#	0.80	0.80	0.80			g#''	0.49	0.49	0.49		
A	0.80	0.81	0.82	0.78	3/0	a''			0.49		
A#	0.78	0.78	0.78			a#''	0.47	0.47	0.47		
B	0.78	0.79	0.77			b''			0.47		
c	0.76	0.76	0.77			c'''			0.48		
c#	0.77	0.77	0.78			c#'''				0.44	2
d	0.78	0.77	0.78			d'''					
d#	0.78	0.78	0.77			d#'''			0.44		
e	0.63	0.63	0.64	0.63	2/0	e'''			0.44		
f	0.63	0.64	0.65			f'''			0.44		
f#	0.63	0.64				f#'''	0.45	0.44	0.44		
g	0.65	0.63				g'''		0.44			
g#						g#'''	0.45	0.45	0.45		
a						a'''	0.44				
a#						a#'''					
b						b'''		0.44			
c'						c''''					
c#'	0.63	0.63	0.63			c#''''		0.39		0.38	3
d'	0.63					d''''			0.37		
d#'	0.54	0.54	0.52	0.53	1/0	d#''''					
e'	0.55	0.54	0.53			e''''					
f'	0.52	0.51				f''''					

Table 27

Diameters of strings found on two pianos by Hofmann, one by Brodmann, one by Streicher and one by Walter und Sohn, averaged for each gauge and compared with the diameters given by Thomée and Huber for the Nuremberg and 'Berlin' systems (all mm)

	Thomée's Nuremberg diameters	Diameters on H/c.1785a	Diameters on H/c.1795c	Diameters on {Wörlitz}	Diameters on S/1819/1415	Diameters on W/c.1817	Huber's 'Berlin' diameters
Maker		Hofmann	Hofmann	Brodmann	Streicher	Walter	
Date		c.1785	c.1795	1818	1819	1817	
Gauge							
9/0	1.10	-	-	1.27	-	-	1.44
8/0	1.06	-	-	1.15	1.30	-	1.30
7/0	0.97	1.02	1.02	1.00	1.20	-	1.14
6/0	0.87	0.92	?	0.86	1.03	0.95	1.01
5/0	0.83	0.85	0.84	0.84	0.87	0.87	0.89
4/0	0.76	0.81	0.78	0.75	0.75	0.79	0.79
3/0	0.66	0.71	0.71	0.69	0.63	0.78	0.72
2/0	0.60	0.61	0.63	0.65	0.56	0.63	0.64
1/0	0.56	0.57	0.61	0.61	0.48	0.53	0.59
1	0.51	0.54	0.53	0.53	-	0.48	0.53
2	0.46	0.51	0.52	0.51	-	0.44	0.47
3	0.41	0.44	?	0.40	-	0.38	0.42
4	0.37	0.37	-	-	-	-	-

Table 28

The hypothesis of a single system in flux is supported by comparing the gauge markings found on the pianos of individual builders. In no builder's career do there appear to be moments at which he or she, presented with a new system, adjusted his or her standard stringing scheme accordingly. The pianos of each maker, taken in chronological order, show a continuous trend towards thicker stringing. There are no sudden discontinuities to suggest the advent of a new gauge system.

A builder like Bleyer (or a theoretician like Karmarsch) equipped himself to measure or calculate diameters to a considerable degree of accuracy and showed a predeliction for the application of *a priori* mathematical principles. A builder like Hofmann, on the other hand, may have had no need of measuring string diameters accurately, preferring to work according to principles of design based in the traditions of his craft, looking to the wire drawers and relying in turn on the traditions of their craft for a supply of wire of the right gauges.

The Nuremberg system, the 'Berlin' system and the Vienna system were probably one and the same expanding system. With time, more and more half gauges were added throughout the system and larger gauges were added for use in the bass. It seems to have been a system of gauges on the move, a system in which the diameter of each nominal gauge grew in diameter, a process which continued until absolute standards were generally established through the widespread use of the micrometer.

CHAPTER IV

THE STRING GAUGE MARKINGS ON THE INSTRUMENTS

In this chapter the gauge markings found on the instruments are discussed. Two types of tables for the gauge markings are given. The first presents the stringing scheme in the traditional manner, giving the notes at which there is a change of gauge. In the second type all the notes are given in order and the note at which each gauge changes is marked with the appropriate gauge. In this second type, a box has been placed around gauge 2/0 to facilitate comparison and thicker lines define the range of each piano.

Hofmann

The grand pianos of Hofmann can be arranged in chronological groups according to various criteria including distinctive decorative features and, more importantly, technical features such as the dimensions of the bridge, the thicknesses of the bridge pins and nut pins, the scaling and the string gauge markings. These groups are:

Group 0	: (H/c.1784a), (H/c.1784b)
Group I	: H/c.1785a, H/c.1785b, H/c.1785c, H/c.1785d
Group II	: H/c.1790b, (H/c.1790a)
Group III	: H/c.1795a, H/c.1795b, H/c.1795c, (H/c.1795d), (H/c.1795e)
Group IIIa	: (H/c.1795f), (H/c.1795g), (H/c.1795h)
Group IV	: H/c.1800
Group V	: H/c.1805
Group VI	: (H/c.1815), H/c.1820

The groups comprising only one or two instruments, should be explained. Hofmann must have built his pianos in series. Each of the above groups probably represents the remaining pianos of one particular series. Because the twenty surviving grand pianos by Hofmann comprise at the most only 5% of his total production over more than 25 years, the number of survivors from each series can only be very small. It is therefore not surprising that some of the groups above contain only one or two instruments. Conversely, we should probably regard each piano which is unlike any other not as made as a unique instrument but as a sole survivor of a series.

Hofmann wrote the string gauges for his instruments in ink or pencil on the front edge of the soundboard under the strings (ill. 1, page 4). A number of his pianos have lost their gauge markings during later repairs involving the cleaning, sanding or replacement of the soundboard. Such pianos have nonetheless been assigned to groups on the basis of the criteria given above. But as it is the pianos with gauge markings which primarily concern us here those without gauge markings are distinguished in the list by giving them in brackets.[168]

The four instruments of group I all have the same string gauges marked for the same notes, as do the three instruments of group III. Because it is most unlikely that an empirical stringing method would have produced identical stringing schemes for each of the four instruments of group I and again for the three instruments of group III there remains little doubt that Hofmann chose the string gauges according to an *a priori* method. The stringing scheme was part of the design of each series of pianos and determined before the instruments were built. Furthermore, if Hofmann had chosen string gauges by ear while stringing each instrument, it would have been much simpler to write or stamp the gauge marks on the wrestplank next to the tuning pins rather than on the soundboard under the strings.

The diameters of the strings on H/c.1820, taken in conjunction with the gauge markings, which include half gauges (...3/0, 3/0$^1/_2$, 2/0, 2/0$^1/_2$, 1/0, 1/0$^1/_2$, 1,...), are close to the diameters Huber gives for his 'Berlin' system.[169] The gauges found marked on the other pianos by Hofmann, all represented by numbers of zeros and whole numbers (...4/0, 3/0, 2/0, 1/0, 1, 2,...), are taken here to refer to the diameters given by Thomée for his

168 See Michael Latcham, 'Soundboards Old & New', *Galpin Society Journal*, XLV, 1992, 50-8.

169 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 217.

Nuremberg system, assuming that the the strings found on H/c.1800 are original. The string gauge markings for each group of pianos by Hofmann are given in tables 29 and 30.

Gauge markings found on pianos by Hofmann

Group:	I	II	III	IV	V	VI
Av. c" length (mm)	296	289	285	283	277	270
Av. FF length (mm)	1632	1633	1632	1631	1631	1762
Date (approximate)	1785	1790	1795	1800	1805	1820
Range	FF-f'''	FF-f'''	FF-g'''	FF-g'''	FF-c''''	FF-f''''
Gauge						
7/0	FF	FF	FF	FF	FF	FF
6/0	GG	GG	GG	GG	GG	GG
5/0	AA#	AA#	AA#	AA#	AA#	AA#
4/0	D	D	D	D	D	D
4/0 '*weiß*'	F	F	F	F	F	F#
4/0½	-	-	-	-	-	A#
3/0	G	G	G	G	G#	d
3/0½	-	-	-	-	-	g
2/0	c	c	c	c#	d	d#'
2/0½	-	-	-	-	-	-
1/0	f	f#	f#	g#	g#	b'
1/0½	-	-	-	-	-	a#''
1	a#	c#'	c'	e'	e'	e'''
2	e'	g'	g#'	c''	c''	-
3	a#'	d''	f''	a''	a''	-
4	g#''	a''	-	-	a'''	-

Table 29

Pianos of Hofmann: Gauge markings

Group	I	II	III	IV	V	VI
Date	c.1785	c.1790	c.1795	c.1800	c.1805	c.1820
Range	FF-f'''	FF-f'''	FF-g'''	FF-g'''	FF-c''''	FF-f''''
c'' length (mm)	296	289	285	283	277	270
(averages)						
FF length (mm)	1632	1633	1632	1631	1631	1762
FF	7/0	7/0	7/0	7/0	7/0	7/0
FF#						
GG	6/0	6/0	6/0	6/0	6/0	6/0
GG#						
AA						
AA#	5/0	5/0	5/0	5/0	5/0	5/0
BB						
C						
C#						
D	4/0	4/0	4/0	4/0	4/0	4/0
D#						
E						
F	4/0 weiß	4/0 weiß	4/0 weiß	4/0 weiß	4/0 weiß	
F#						4/0 weiß
G	3/0	3/0	3/0	3/0		
G#					3/0	
A						
A#						
B						
c	2/0	2/0	2/0			
c#				2/0		
d					2/0	
d#						
e						
f	1/0					
f#		1/0	1/0			
g						3/0 half
g#				1/0	1/0	
a						
a#	1					
b						
c'			1			
c#'		1				
d'						
d#'						2/0
e'	2			1	1	
f'						
f#'						
g'		2				
g#'			2			
a'						
a#'	3					
b'						1/0
c''				2	2	
c#''						
d''		3				
d#''						
e''						
f''			3			
f#''						
g''						
g#''	4					
a''		4		3	3	
a#''						1/0 half
b''						
c'''						
c#'''						
d'''						
d#'''						
e'''						1
f'''						
f#'''						
g'''						
g#'''						
a'''					4	
a#'''						
b'''						
c''''						
c#''''						
d''''						
d#''''						
e''''						
f''''						

Table 30

The groups are arranged chronologically. Reading across each row for the iron gauges in table 29 it will be seen that where there are differences, the later the group, the higher each gauge is taken. In other words, the later the instrument, the thicker the strings. The smooth progress of this tendency from group I through to group V is consistent with the idea that Hofmann employed the same gauge system for the pianos of all these groups, that is until at least 1805.

H/c.1820 lacks the marking for gauge $2/0^1/_2$. It may have been cleaned away although gauge $2/0^1/_2$ in Huber's 'Berlin' system (0.61mm) is not appreciably different in size to gauge 1/0 (0.59mm) and for this reason may possibly have been omitted.

It is worth considering what the stringing schemes might have been on some of the instruments which have lost their string gauge markings. To do this it is necessary to look at some other aspects of these pianos. The action of H/c.1784a appears to have been made largely in imitation of Stein's work, that is, before Hofmann had fully developed the action design he used in the majority of his pianos. For instance, there is no hammer check and the *Kapseln* are wooden. On the grounds of these and other similarities with Stein's pianos, one might expect that H/c.1784a would have had Stein's lighter stringing in the bass, starting with gauge 5/0 at FF (S/1782, S/1786 and S/1788a) rather than the heavier stringing of all the pianos of Hofmann which have retained their string gauge markings. These all begin in the bass with gauge 7/0 for FF. The internal structure of H/c.1784a, however, is the same as in all the pianos up to and including group V. Although this structure is clearly derived from the internal structure of

Stein's later pianos it is conceived on stronger lines. For this reason it is more likely that in the bass H/c.1784a was strung like the pianos of groups II to V, all of which start with gauge 7/0 at FF.

H/c.1784b has a more developed action than H/c.1784a. The *Kapseln* are of brass and there is a rudimentary hammer back check, although not the ingenious back check found in the pianos of groups II to V.[170] But both H/c.1784a and H/c.1784b have a relatively long scaling in the treble, with c" string lengths of 309mm and 306mm respectively. These two instruments may therefore have been more lightly strung in the treble than the group I pianos. These details are summarized in table 31.

170 See Michael Latcham, 'The check in some early pianos and the development of piano technique around the turn of the 18th century', *Early Music*, XXI/1, Feb. 1993, 28-42.

Comparison of the scalings and string gauge markings of one piano by Stein and three by Hofmann

	FF length mm	Gauge at FF	c" length mm	Gauge at c"
S/1788a	1705	5/0	296	3
H/c.1784a	1637	? 7/0	309	? 4
H/c.1784b	1633	? 7/0	306	? 4
H/c.1785c	1633	7/0	292	3

Table 31

Group IIIa comprises three instruments which were probably made for use at a higher pitch. All three are of about the same date as those in group III. Because the scaling of each of the three is shorter than normal, to an extent equivalent to a semitone in pitch, one would have expected them to have had gauge changes consistently a semitone lower (on the keyboard rather than for the ear) than those of the pianos in group III. It is therefore unfortunate that none of the three has retained any gauge marks which might have been used to confirm or refute this.

Walter

Walter does not appear to have marked string gauges on all his pianos. The gauge markings which exist are either written or stamped on the wrestplank next to the tuning-pins. Those pianos with complete sets of gauge markings and the incomplete set on W/c.1820 are given in tables 32 and 33. The gauge markings on W/c.1782b, in pencil, although documented as recent, are also included. They may have been copied from the originals.[171]

171 The author is grateful to the late Kurt Wittmayer for this information.

Gauge markings found on pianos by Walter

W/	1782b	1796	c.1800b	c.1800e	c.1805a	c.1815f	c.1817	c.1820
c" (mm)	296	275	278	282	286	287	285	270*
FF (mm)	1771	1769	1737	1735	1721	1747	1745	1747*
Range	FF-f"' not original	FF-f"'	FF-g"'	FF-g"'	FF-c""	FF-f"'	FF-f"'	CC-f"'
7/0 yellow brass	-	-	-	-	-	FF	-	?
6/0 red brass	-	-	FF	FF	FF?	-	-	-
6/0 yellow brass	-	FF	-	-	-	FF#	FF	?
5/0 red brass	-	-	GG	GG	GG?	-	-	-
5/0 yellow brass	FF	GG#	GG#	GG#	AA#?	GG#	GG#	?
5/0 iron	-	-	-	-	-	-	-	F#
5/0½ iron	-	-	-	-	-	-	-	A#
4/0 yellow brass	GG	C	AA#	AA	?	BB	C	-
4/0 iron	-	-	-	-	-	-	E	d
4/0½ iron	-	-	-	-	-	-	-	a#
3/0 yellow brass	AA	D	D	C#	D?	D#	-	-
3/0 iron	-	-	E	D#	E	-	A#	d#'
3/0½ iron	-	-	-	-	-	-	-	a'
2/0 yellow brass	C	-	-	-	-	-	-	-
2/0 iron	D#	A#	A#	G#	G#	A#	e	d#"
2/0½ iron	-	-	-	-	-	-	-	-
1/0	G#	f#	f#	e	d#	f#	d#'	c#"'?
1/0½	-	-	-	-	-	-	-	g#"'?
1	f#	d'	d'	d'	c#'	d#'	f#"	-
2	d'	a#'	a#'	a#'	a#'	d#"	c#"'	-
3	a'	e"	f#"	g"	f#"	f#"'	c#""	-
4	c#"	c#"'	d"'	e"'	e"'	c#""	-	-
5	g"	-	-	-	-	-	-	-

Table 32

Pianos by Walter: String gauge markings

Code	W/c.1782/b	W/1796	W/c.1800b	W/c.1800e	W/c.1805a	W/c.1815f	W/c.1817	W/c.1820
	gauges not							
	original							
c2 length (mm)	296	275	278	282	286	287	285	270*
FF length (mm)	1771	1769	1737	1735	1721	1747	1745	1747*
Range	FF-f'''	FF-f'''	FF-g'''	FF-g'''	FF-c''''	FF-f''''	FF-f''''	CC-f''''
CC								
CC#								
DD								
DD#								
EE								
FF	5/0	6/0	6/0	6/0	[6/0]	7/0	6/0	
FF#						6/0		
GG	4/0	5/0	5/0	5/0	[5/0]	5/0		
GG#							5/0	
AA	3/0			5/0				
AA#			5/0					
BB				4/0	[4/0]	4/0		
C	2/0	4/0	4/0				4/0	
C#				3/0				
D		3/0	3/0					
D#	2/0			3/0		3/0		
E			3/0		3/0		4/0	
F								
F#								5/0
G								
G#	1/0			2/0	2/0			
A								
A#		2/0	2/0			2/0	3/0	5/0 half
B								
c								
c#								
d								4/0
d#					1/0			
e				1/0			2/0	
f								
f#	1	1/0	1/0			1/0		
g								
g#								
a								
a#								4/0 half
b								
c'								
c#'					1			
d'	2	1	1	1				
d#'						1	1/0	3/0
e'								
f'								
f#'								
g'								
g#'								
a'	3							3/0 half
a#'		2	2	2	2			
b'								
c''								
c#''	4							
d''								2/0
d#''		3				2		
e''								
f''								
f#''			3		3		1	
g''	5			3				
g#''								
a''								
a#''								
b''								
c'''								1/0?
c#'''		4					2	
d'''			4					
d#'''								
e'''				4	4			
f'''								
f#'''						3		
g'''								
g#'''								1/0 half?
a'''								
a#'''								
b'''								
c''''								
c#''''						4	3	
d''''								
d#''''								
e''''								
f''''								

Table 33

Leaving W/c.1820 aside for the moment we can assume that all the surviving grand pianos by Walter except W/c.1820 were strung according to the same system. There is no sudden discontinuity in the pattern in which the positions of the string gauges change from one instrument to the next. We would expect such a discontinuity if there had been a change in the gauge system used by Walter.

There are several six-octave pianos by Walter similar to W/c.1815f with incomplete sets of gauge markings, usually starting with gauge 3/0 at F. The gauge markings of five of these are given in tables 34 and 35.

The general design of W/c.1820 is very different to that of the earlier pianos by the Walter firm. The string gauges marked indicate that this piano was in any case more heavily strung than the earlier instruments. Not only that, the instrument was probably originally strung with wire of larger diameters for each gauge than the earlier instruments, perhaps with the diameters given by Huber for his 'Berlin' system. W/c.1820 is of the same age as those instruments in which strings of diameters conforming to the 'Berlin' system were used, for instance H/c.1820. On the other hand, the diameters of the strings now on W/c.1820 fit the even heavier Vienna system. These strings might be original or could be the result of a later re-stringing.

Gauge markings found on six pianos by Walter of about 1815, all of six octaves (FF-f''')

W/	c.1815a	c.1815b	c.1815c	c.1815d	c.1815e	c.1815f
c'' (mm) FF (mm)	267 1749	282 1737	289 1742	285 1742	286 1741	287 1747
7/0 yellow brass	-	-	-	-	-	FF
6/0 yellow brass	-	-	-	-	-	FF#
5/0 yellow brass	-	-	-	-	-	GG#
4/0 yellow brass	-	-	-	D	-	BB
3/0 yellow brass	-	-	-	-	D	D#
3/0 iron	F	F	F	F	F	-
2/0 iron	d	c	A#	B	B	A#
1/0 iron	c'	g#	a	a#	g#	f#
1	a#'	f#'	-	a#'	e'	d#'
2	a''	e''	-	a#''	d''	d#''
3	c#'''	d#'''	-	a#'''	d'''	f#'''
4	-	c#''''	-	-	c#''''	c#''''

Table 34

Note: The soundboard of W/c.1815b is probably recent. The two string lengths given here may therefore not reflect the original lengths.

Six pianos by Walter of c.1815: gauge markings

Code	W/c.1815a	W/c.1815b	W/c.1815c	W/c.1815d	W/c.1815e	W/c.1815f
Range	FF-f''''	FF-f''''	FF-f''''	FF-f''''	FF-f''''	FF-f''''
c2 length (mm)	267	282	286	285	285	287
FF length (mm)	1749	1737	1742	1742	1741	1747
FF						7/0
FF#						6/0
GG						5/0
GG#						
AA						
AA#						
BB						4/0
C						
C#						
D				4/0	3/0	
D#						3/0
E						
F	3/0	3/0	3/0	3/0	3/0	
F#						
G						
G#						
A						
A#			2/0	2/0		2/0
B					2/0	
c		2/0				
c#						
d	2/0					
d#						
e						
f						
f#						1/0
g					1/0	
g#		1/0				
a			1/0			
a#				1/0		
b						
c'	1/0					
c#'						
d'						
d#'					1	1
e'						
f'						
f#'		1				
g'						
g#'						
a'						
a#'	1			1		
b'						
c''						
c#''					2	
d''						
d#''						2
e''		2				
f''						
f#''						
g''						
g#''						
a''	2					
a#''				2		
b''						
c'''						
c#'''	3				3	
d'''						
d#'''		3				
e'''						
f'''						
f#'''						3
g'''						
g#'''						
a'''						
a#'''				3		
b'''						
c''''						
c#''''		4			4	4
d''''						
d#''''						
e''''						
f''''						

Table 35

The pianos of Hofmann, despite the small number which has survived, show remarkable consistency in their stringing schemes, allowing us to draw reasonably firm conclusions about Hofmann's stringing practice. No two of the twelve pianos by the Walter firm with partial or complete sets of gauge markings, on the other hand, have the same gauges marked at exactly the same places, which, combined with the fact that so few pianos by the Walter firm have survived, makes it difficult to draw general conclusions about the firm's stringing practice. The comments which now follow should thus be regarded with caution.

Let us assume that all the instruments of the Walter firm, except W/c.1820, were strung using the same diameters for each gauge. We can then say that for all the pianos given here, except W/c.1817 and W/c.1820, the gauge markings in the bass, from gauge 6/0 to gauge 2/0, remain more or less in the same positions. In the treble, on the other hand, all Walter's instruments roughly follow the same pattern as in the pianos of Hofmann: the later the piano, the heavier the stringing. Gauges 3 and 4 either remain in the same positions or are placed higher in the compass in each successive instrument. But the apparently more random positions of other gauges, for instance gauge 1/0, suggest that Walter choose the appropriate gauges as he strung his pianos, perhaps as his ear dictated, rather than according to preconceived schemes. The gauge markings found on pianos of the Walter firm are written or stamped on the wrestplank, a place still easily accessible after stringing, which tends to confirm this idea of *a posteriori* stringing.

Stein and Streicher

There are gauge markings on three of Stein's pianos but only one of these, S/1788a, has a complete set, written in ink on the wrestplank. There is evidence in Stein's notebook to suggest that he maintained more or less the same stringing scheme for his pianos for most of his career. Of the lists for pianos, harpsichords and clavichords found in the notebook only one, on page 248, appears to have been for Stein's own use when stringing grand pianos:

FF	GG	AA#	D	F#	c	a	a'	a"	d#'''
00000	0000	000	00	*Weiss*	1	2	3	4	5

This list is compared with the complete set of gauge markings on S/1788a and with the incomplete sets on S/1782 and S/1786 in table 36. The date 1777 is found in the notebook on page 283, so it seems safe to assume that Stein was already using the stringing scheme on page 248 before 1777.

Stringing schemes used by Stein

	before 1777	S/1782	S/1788a	S/1786
5/O	FF	FF	FF	FF
4/O	GG	GG	GG	GG
3/O	AA#	AA	AA#	AA#
2/O	D	C	C#	D
O	-	E	E	E
O (Steel)	F#	?	F#	-
1	c	?	c	c?
2	a	?	b	?
3	a'	?	a#'	?
4	a"	?	f#"	?
5	d#"'	?	d"'	?

Table 36

Assuming that all four sets of gauge numbers refer to the same absolute diameters, the differences amongst these stringing schemes are small. There appears to have been no appreciable change in Stein's stringing practice for grand pianos between the period prior to about 1777 and the period around 1788 when S/1788a was built.

Only six of the surviving pianos made by Nannette Streicher between about 1804 and 1819 have string gauges marked but from 1820 onwards almost all of the instruments produced by the Streicher firm have retained their gauge markings. All the complete sets of gauges marked on the pianos by Stein and the Streicher firm from 1788 to 1819, together with a representative selection of those of the Streicher firm from 1820 to 1839, are given in tables 37 and 38.

Gauge markings found on pianos of the Stein and Streicher firm

date	S/1788a	S/c1804a	S/1807	S/1808	S/1811	S/1816	S/1819	S/1820	S/1823	S/1830	S/1839
prod.nr	-	-	733	764	908	1117	1415	1550	1756	2383	3304
c" (mm)	296	279	285	275	267	*265*	265	272	271	275	288*
FF (mm)	1705	1678	1892	1884	1757	*1827*	1867	1860*	1910	1807	1862*
CC (mm)	-	-	1956	1962	-	-	-	-	2004	-	1965*
Range	FF-f"'	FF-c""	CC-f""	CC-f""	FF-f""	FF-f""	FF-f""	FF-f""	CC-f"'	FF-f""	CC-g"'
Split bridge?	no	no	F/F$^{\#}$	no	F/F$^{\#}$	no	no	no	F/F$^{\#}$	F/F$^{\#}$	F/F$^{\#}$
12/0	-	-	-	-	-	-	-	-	?	-	CC
11/0	-	-	CC	-	-	-	-	-	?	-	CC$^{\#}$
10/0	-	-	CC$^{\#}$	CC	-	-	-	-	?	-	DD
9/0	-	-	EE	DD	-	-	-	-	?	-	DD$^{\#}$
8/0	-	-	FF	EE	FF	FF?	FF	FF	?	FF	EE
8/0½	-	-	-	-	-	-	-	-	-	-	FF$^{\#}$
7/0	-	FF	GG	GG	GG	GG?	GG	GG	FF$^{\#}$	GG	GG
7/0½	-	-	-	-	-	-	-	-	-	-	GG$^{\#}$
6/0	-	GG	AA	AA	AA	AA	AA	AA	GG$^{\#}$	AA	AA
6/0½	-	-	-	-	-	-	-	-	-	-	AA$^{\#}$
5/0 br.	FF	AA	BB	BB	BB	BB	BB	BB	AA$^{\#}$	BB	BB
5/0 Fe	-	-	-	-	-	-	-	-	-	-	F$^{\#}$
5/0½br	-	-	-	-	-	-	-	-	-	-	C$^{\#}$
4/0 br.	GG	BB	C$^{\#}$	C$^{\#}$	C$^{\#}$	C$^{\#}$	C$^{\#}$	C$^{\#}$	D	D	D
4/0 Fe	-	-	-	-	-	D$^{\#}$	D$^{\#}$	D$^{\#}$	F$^{\#}$	F$^{\#}$	d
4/0½ Fe	-	-	-	-	-	-	-	-	-	-	g
3/0 br.	AA$^{\#}$	D$^{\#}$	D$^{\#}$	E	D$^{\#}$	-	-	-	-	-	-
3/0 Fe	-	F$^{\#}$	F$^{\#}$	-	F$^{\#}$	F$^{\#}$	F$^{\#}$	A	A$^{\#}$	A$^{\#}$	a$^{\#}$
3/0½	-	-	-	-	-	-	-	f$^{\#}$	g	g	d$^{\#}$'

Table 37

Gauge markings found on pianos of the Stein and Streicher firm (cont.)

date	1788a	c.1804	1807	1808	1811	1816	1819	1820	1823	1830	1839
prod.nr	-	-	733	764	908	1117	1415	1550	1756	2383	3304
c" (mm)	296	279	285	275	267	264	265	265*	271	275	288*
Range	FF-f"'	FF-c""	CC-f""	CC-f""	FF-f""	FF-f""	FF-f""	FF-f""	CC-f"'	FF-f""	CC-g"'
2/0 br.	C#	-	-	-	-	-	-	-	-	-	-
2/0 Fe	-	A	A	c	A	A	A	c'	c'	c'	g#'
2/0½	-	-	-	-	-	-	-	e"	d#"	d#"	d#"
1/0 br.	E	-	-	-	-	-	-	-	-	-	-
1/0 Fe	F#	c	c	g#	c	c'	c#'	f'"	f'"	f'"	c#'"
0½	-	-	-	-	b'	d#"	d#"	-	-	-	g#"'
1	c	f#	g'	g#'	f"'	f"'	f"'	c""	c""	c""	c""
1½	-	-	-	-	-	-	-	-	-	-	e""
2	b	a'	c""	c#""	c""	c""	c""	-	-	-	-
3	a#'	f"	-	-	-	-	-	-	-	-	-
4	f#"	c#'"	-	-	-	-	-	-	-	-	-
5	d'"	g'"	-	-	-	-	-	-	-	-	-

Table 37 (continued)

Note: the soundboard of S/1816/1117 is recent so that the string lengths given here for that piano cannot be trusted.

Pianos of the Stein/Streicher dynasty 1788-1839
String gauge markings

Maker	J.A. Stein	N. Streicher	N. Streicher	N. Streicher	N. Streicher	N. Streicher	N. Streicher	N. Streicher	N. Streicher	Streicher&So	J.B. Streicher
Code	S/1788a	S/c.1804a	S/1807/733	S/1808/764	S/1811/908	S/1816/1117	S/1819/1415	S/1820/1550	S/1823/1756	S/1830/2383	S/1839/3304
Range	FF-f"'	FF-c""	CC-f""	CC-f""	FF-f""	FF-f""	FF-f""	FF-f""	CC-f""	FF-f""	CC-g""
Split bridge?	no	no	F/F#	no	F/F#	no	no	no	F/F#	F/F#	F/F#
c" length (mm)	296	279	285	275	267	264 n/o	265	272	271	275	288*
FF length (mm)	1705	1678	1892	1884	1757	1827 n/o	1867	1860*	1910	1807	1862*
CC length (mm)	-	-	1956	1962	-	-	-	-	2004	-	1965*
CC			11/0	10/0		new			?		12/0
CC#			10/0			soundboard			?		11/0
DD				9/0					?		10/0
DD#											9/0
EE			9/0	8/0					?		8/0
FF	5/0	7/0	8/0		8/0	8/0?	8/0	8/0		8/0	
FF#									7/0		8/0 half
GG	4/0	6/0	7/0	7/0	7/0	7/0?	7/0	7/0		7/0	7/0
GG#									6/0		7/0 half
AA		5/0	6/0	6/0	6/0	6/0	6/0	6/0		6/0	6/0
AA#	3/0								5/0		6/0 half
BB		4/0	5/0	5/0	5/0	5/0	5/0	5/0		5/0	5/0
C											
C#	2/0		4/0	4/0	4/0	4/0	4/0	4/0			5/0 half
D									4/0	4/0	4/0
D#		3/0	3/0		3/0	4/0	4/0	4/0			
E	1/0			3/0							
F											
F#		3/0	3/0		3/0	3/0	3/0		4/0	4/0	5/0
G											
G#											
A		2/0	2/0		2/0	2/0	2/0	3/0			
A#									3/0	3/0	5/0 half
B											
c	1	1/0	1/0	2/0	1/0						
c#							1/0				
d											4/0
d#											
e											
f											
f#		1						3/0 half			
g									3/0 half	3/0 half	4/0 half
g#				1/0							
a											
a#											3/0
b	2										
c'						1/0		2/0	2/0	2/0	
c#'											
d'											
d#'											3/0 half
e'											
f'											
f#'											
g'			1								
g#'				1							2/0
a'		2									
a#'	3										
b'					1/0 half						
c"											
c#"											
d"									2/0 half		
d#"						1/0 half	1/0 half			2/0 half	2/0 half
e"								2/0 half			
f"		3									
f#"	4										
g"											
g#"											
a"											
a#"											
b"											
c"'											
c#"'		4									1/0
d"'	5										
d#"'											
e"'											
f"'					1	1	1	1/0	1/0	1/0	
f#"'											
g"'		5									
g#"'											1/0 half
a"'											
a#"'											
b"'											
c""			2		2	2	2	1	1	1	1
c#""				2							
d""											
d#""											
e""											1 half
f""											
f#""											
g""											
g#""											
a""											

Table 38

The gauge markings found on the pianos by the Streicher firm can tentatively be interpreted as follows. On the basis of the strings found on two pianos, S/c.1804b and S/1807/733 the firm probably continued to use the diameters of Thomée's Nuremberg system until at least 1807.[172] Subsequently, from sometime after 1811 but in any case in 1819 the firm may have used slightly different diameters, thinner in the treble but thicker in the bass, belonging to another system, the 'Streicher 1819' system. Finally, from at least 1835 onwards and probably already in 1826, the firm used the generally thicker diameters for each nominal gauge which correspond to those measured by the caliper used by the Streicher firm preserved in the Technisches Museum in Vienna.

But the idea that the Streicher firm changed gauge systems is largely contradicted by the lack of any sudden changes in the stringing schemes used. The gradual process in which changes were made, indicating not a plurality of systems but one single system, will now be outlined.

There are numerous instruments made by the Streicher firm which more or less fall into groups according to their gauge markings (see tables 37 and 38). The first of these groups comprises those pianos made in 1807, 1811, 1816 and 1819. The 1807 and 1811 pianos were probably strung according to the same basic scheme but with some adjustments made in the treble. The 1807 piano changes to gauge 1 at g' and has no half gauges

172 See H. Thomée, 'Untersuchungen über Draht- und Blechlehren', *Zeitschrift des Vereines Deutscher Ingineure*, X, 1866, 659-60.

marked. The 1811 piano includes a single half gauge, $1/0\frac{1}{2}$ at b' and the change to gauge 1 comes at f'''. The stringing schemes of the other two members of the group, S/1816/1117 and S/1819/1415, appear to be based on the scheme used for the 1807 and 1811 pianos. The positions of the gauge markings in the bass are the same for all four instruments except that the 1816 and 1819 pianos change to iron lower down, at D#, than in the 1807 and 1811 pianos which change at F#. This difference reflects the fact that while both the 1807 and 1811 pianos have bridges divided for brass and iron at F/F# the 1816 and 1819 instruments have a single bridge.

Moving up in the compass, the two subsequent gauges, 3/0 and 2/0, are marked at the same places (F# and A) in all four pianos of this group. Some variation then follows. Gauge 1/0 is placed an octave higher in the 1816 and 1819 pianos and gauge $1/0\frac{1}{2}$ is placed four semitones higher than in the 1811 piano. But gauges 1 and 2 are again assigned to the notes f''' and c'''' respectively, as in the 1811 piano.

The next group of pianos comprises six instruments dated between 1820 and 1830.[173] These six, represented in tables 37 and 38 by S/1820/1550, S/1823/1756 and S/1830/2383, all have very similar stringing schemes (three are identical to each other). The positions for the brass gauges are the same as those in the 1816 and 1819 pianos except that the stringing scheme in the bass

173 S/1820/1550, S/1823/1756, S/1826/2053, S/1827/2185, S/1828/2237 and S/1830/2383.

of S/1823/1756 is slightly heavier.

The positions for the iron gauges in the 1820-1830 group may have been derived from the positions of the iron gauges in the 1816 and 1819 pianos as follows. The position occupied by gauge 2/0 in the 1816 and 1819 pianos is given to gauge 3/0 in the 1820-1830 pianos; the position occupied by 3/0 in the 1816 and 1819 pianos is given to gauge 4/0 in the later group and so on, such that the notes strung in iron of the later group are all strung one whole gauge heavier than in the 1816 and 1819 pianos. At the same time gauge $3/0^1/_2$ is interpolated between gauges 3/0 and 2/0 in the later group. Except the two thinnest gauges (1/0 and 1), which are in the same places in all six pianos of this group, the exact positioning of the other gauges again shows some minor variation.

The sudden jump in the iron section of the stringing scheme to a whole number 'heavier' from one group to the next could suggest a change to a new gauge system in which the diameters for each gauge were thinner (by one gauge) than those of the system previously used. This seems unlikely, however. In general, the actual diameters of each nominal gauge became thicker, never thinner. For instance, gauge 4/0 is 0.76mm in the Nuremberg system as reported by Thomée, 0.79mm in Huber's 'Berlin' system and 0.93mm thick in Streicher's Vienna system. Apparently, in about 1820, the decision was taken by the Streicher firm to change their design by stringing the iron section one whole gauge heavier.

Next comes a small group comprising just two pianos, S/1832/2584 and S/1835/2750, again with very similar although not identical stringing schemes. Both are down-striking instruments without a divided bridge. The stringing scheme exhibited by these two does not appear to be derived from that of the previous group. More groups of later dates can also be identified.

None of these groups is, in itself, completely consistent with respect to the stringing schemes of its members. Furthermore, at each period there are exceptional instruments which do not fit into any group. The 1808 instrument, for instance, does not appear to belong to the same group as the 1807 and 1811 instruments. This perhaps reflects a remark made by Lütge in his discussion of the correspondence between Härtel and Andreas Streicher:

> 'Streicher's letters [to Härtel] reveal the interesting fact that in those days [1800-1807] the pianos were not produced by the factory in series. In this way the public did not have to make a choice between instruments which were already finished but rather the pianos were built to conform to the individual wishes of the client. The piano was given a stronger or softer sound according to the taste of the particular buyer.'[174]

Although it seems certain that the Streicher firm did produce their pianos in series we can imagine that the wishes of the client would

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174 '*Es ergibt sich aus Streichers Briefen [an Härtel] die interessante Tatsache, dass damals die Klaviere nicht serienweise von der Fabrik geliefert wurden, das Publikum also nicht genötigt war, mit den einmal hergestellten Instrumenten vorlieb zu nehmen, sondern dass die Klaviere den individuellen Wünschen des Bestellers gemäss gebaut wurden; je nach dem Geschmack des betreffenden Liebhabers erhielt das Klavier einen starken oder leiseren Ton* [...].' Wilhelm Lütge, 'Andreas und Nannette Streicher', *Der Bär, Jahrbuch von Breitkopf und Härtel*, Leipzig 1927, 62. The original letters were lost in the second world war.

have been respected as far as possible. It would not have been difficult, for instance, to regulate the available volume by adjusting the thicknesses of the strings. A piano for a client who required more volume would have perhaps been strung with thicker strings. But in practice, with a production of more than two instruments every week, the Streicher firm must have standardised their production. This might have included a choice of standard stringing patterns from which to select when considering the particular needs of the buyer. But the wishes of the client to which Streicher referred were probably more often related to decorative features such as the choice of the exterior wood.

The close similarities within the existing groups, combined with the small but detailed inconsistencies within each of those groups suggest that like Walter but unlike Hofmann, the Streicher firm decided on the exact changeover points from one gauge to another whilst stringing, that is, they strung by ear, making small individual adjustments to pre-ordained patterns. In the article entitled '*Bezug*' or stringing in Schilling's '*Encyclopädie*' (1835), there is clear evidence that in practice instruments were at least partially strung by ear:

> 'Each dimension of the soundboard, as also generally the construction of the instrument, requires a different division of the stringing; only general rules can be set down. As far as the brass strings of the lower notes are concerned, the ear decides if they must be covered or not.'[175]

175 Schilling, ed. *Encyclopädie*, I, 1835, 624, art. '*Bezug*', '*Jede Dimension des Resonanzbodens, so wie überhaupt die Construction des Instruments verlangt eine andere Eintheilung des Bezugs; daher lassen sich nur allgemeine Regeln über denselben festsetzen* [...]. *Was die Messingsaiten*

It is also probable that from at least 1820 onwards the Streicher firm built different series of pianos concurrently and that for each series there was a standard stringing scheme, depending, for instance, on the type of instrument (down-striking or not), the overall length, the range and whether the bridge was divided for brass and iron strings. There may also have been experimental prototypes, such as the English style piano, S/1847/3739. An appropriate stringing list for each of these series and types was probably devised beforehand and varied in practice. In tables 39 and 40 the string gauges marked on five Streicher pianos of the same period are given. These pianos illustrate the consistency found in string gauge markings within a single period, the variation depending on the type of instrument and the subtle differences within the members of a single group.

der tieferen Töne betrifft, [...] das Gehör entscheidet, ob sie übersponnen werden müssen oder nicht.'

Gauges marked on five pianos by Streicher, all with a range from CC to g'''' and all built between 1837 and 1839

Date/Prod.Nr.		1837/2991	1839/3261	1839/3299	1839/3304	1839/3338
Action type		Down-Striking	*Prell-mechanik*	*Stoß-mechanik*	Down-striking	*Prell-mechanik*
Length CC/c''		1967/273	1892/278	1775/271	1965/288	1883/283
Covered strings		None	CC-EE	CC-C#	None	CC-EE
	String Gauges					
Brass	12/0	CC	-	-	CC	-
	11/0	CC#	-	-	CC#	-
	10/0	DD	-	-	DD	-
	9/0	DD#	-	-	DD#	-
	8/0	EE	FF	-	EE	FF
	8/0½	FF#	FF#	-	FF#	FF#
	7/0	GG	GG	-	GG	GG
	7/0½	GG#	GG#	-	GG#	GG#
	6/0	AA	AA	-	AA	AA
	6/0½	AA#	AA#	-	AA#	AA#
	5/0	BB	BB	-	BB	BB
	5/0½	C#	C#	-	C#	C#
	4/0	D	-	-	D	-
	4/0½	E	-	-	-	-
Iron	6/0	F#	D	D	-	D
	6/0½	G#	E	E	-	E
	5/0	A#	F#	F#	F#	F#
	5/0½	c#	A#	A#	A#	A#
	4/0	f	d	d	d	d
	4/0½	e'	g	?	g	g
	3/0	a'	b	b	a#	b
	3/0½	d#''	d#'	d#'	d#'	d#'
	2/0	a''	g'	g'	g#'	g#'
	2/0½	d#'''	d#''	d#''	d#''	d#''
	1/0	g#'''	c#'''	c#'''	c#'''	c#'''
	1/0½	d''''	g#'''	g#'''	g#'''	g#'''
	1	-	c''''	c''''	c''''	-
	1½	-	e''''	e''''	e''''	e''''

Table 39

Five pianos by J.B. Streicher of the same period
String gauge markings

Maker	J.B. Streicher	J.B. Streicher	J.B. Streicher	J.B. Streicher	J.B. Streicher
Code	S/1837/2991	S/1839/3261	S/1839/3299	S/1839/3304	S/1839/3338
Range	CC-g**	CC-g**	CC-g**	CC-g**	CC-g**
Split bridge?	no	C#/D	C#/D	F/F#	C#/D
Action	Down-striking	*Prellmechanik*	*Stoßmechanik*	Down-striking	*Prellmechanik*
Covered strings	none	CC-EE	CC-C#	none	CC-EE
c2 length (mm)	273*	278	271*	288*	291
CC length (mm)	1967*	1892	1775*	1965*	1883
CC	12/0			12/0	
CC#	11/0			11/0	
DD	10/0			10/0	
DD#	9/0			9/0	
EE	8/0			8/0	
FF		8/0			8/0
FF#	8/0 half	8/0 half		8/0 half	8/0 half
GG	7/0	7/0		7/0	7/0
GG#	7/0 half	7/0 half		7/0 half	7/0 half
AA	6/0	6/0		6/0	6/0
AA#	6/0 half	6/0 half		6/0 half	6/0 half
BB	5/0	5/0		5/0	5/0
C					
C#	5/0 half	5/0 half		5/0 half	5/0 half
D	4/0	6/0	6/0	4/0	6/0
D#					
E	4/0 half	6/0 half	6/0 half		6/0 half
F					
F#	6/0	5/0	5/0	5/0	5/0
G					
G#	6/0 half				
A					
A#	5/0	5/0 half	5/0 half	5/0 half	5/0 half
B					
c					
c#	5/0 half				
d		4/0	4/0	4/0	4/0
d#					
e					
f	4/0				
f#					
g		4/0 half		4/0 half	4/0 half
g#					
a					
a#				3/0	
h		3/0	3/0		3/0
c'					
c#'					
d'					
d#'		3/0 half	3/0 half	3/0 half	3/0 half
e'	4/0 half				
f'					
f#'					
g'		2/0	2/0		
g#'				2/0	2/0
a'	3/0				
a#'					
b'					
c*					
c#*					
d*					
d#*	3/0 half	2/0 half	2/0 half	2/0 half	2/0 half
e*					
f*					
f#*					
g*					
g#*					
a*	2/0				
a#*					
b*					
c*'					
c#*'		1/0	1/0	1/0	1/0
d*'					
d#*'	2/0 half				
e*'					
f*'					
f#*'					
g*'					
g#*'	1/0	1/0 half	1/0 half	1/0 half	1/0 half
a*'					
a#*'					
b*'					
c**		1	1	1	
c#**					
d**	1/0 half				
d#**					
e**		1 half	1 half	1 half	1 half
f**					
f#**					
g**					
g#**					
a**					

Table 40

Könnicke

None of the seven grand pianos of Johann Jakob Könnicke, dating from between about 1795 and 1810, has string gauges marked.[176]

Schantz

None of the surviving pianos built by Johann Schantz in the period between 1791, when he began as a piano maker, and about 1815 has string gauges marked except for one of about 1795 (Sz/4a) which has an incomplete set. After 1815 Schantz's pianos usually do have gauges marked, often written in pencil on the bridge, sometimes stamped or written in ink on the wrestplank and in one case written under the strings on the nut such that the gauges can only be read if the strings are removed. The gauges found marked on twelve pianos by Schantz are given in tables 41 and 42.

176 K/1 to K/7.

String gauges marked on thirteen pianos by Schantz

Code	Sz/4a	Sz/10	Sz/11	Sz/12	Sz/12a	Sz/14	Sz/15	Sz/16a	Sz/17	Sz/18	Sz/19	Sz/20	Sz/22
date	c.1795	c.1815	c.1815	1821	c.1820	c.1820	c.1820	c.1825	c.1825	c.1825	c.1825	c.1825	c.1825
c" (mm)	287	276	276	281	275		272	268	268*	268	267	273	268
FF (mm)	1800	1831	1815	1770	1771		1771	1838	1867*	1875	1861	1903	1883
Range	FF-c''''	FF-f''''	FF-f''''	FF-f''''	FF-f''''	CC-f''''	CC-f''''	FF-f''''	FF-f''''	FF-f''''	CC-f''''	FF-f''''	FF-g''''
Split bridge?	G/G#	G/G#	no	no	no	no	no	F/F#	F/F#	F/F#	F/F#	F/F#	F/F#
10/0 brass	-	-	-	-	-	?	CC	-	-	-	-	-	-
9/0	-	-	-	-	-	?	DD	-	-	-	-	-	-
8/0	-	FF	FF	FF	FF	FF	FF	FF	FF	FF	CC	FF	FF
8/0½	-	-	-	-	-	-	-	-	FF#	FF#	DD#	FF#	FF#
7/0	-	GG	GG	GG	GG	GG	GG	GG	GG	GG	GG	GG	GG
6/0	FF	AA	AA#	AA#	AA#	AA#	AA	AA	AA	AA	AA	AA	AA
5/0 brass	FF#	BB	C#	D	D	D	C	C	C	C	C	C	C
5/0 iron	-	-	-	F#	F#	-	-	-	-	-	-	-	-
5/0½ iron	-	-	-	A	-	F#	-	-	-	-	-	-	-
4/0 brass	GG#	D	D#	-	-	-	D#	E	D#	D#	D#	D#	D#
4/0 iron	-	F#	-	B	A#	A	F#	F#	F#	F#	F#	F#	F#
4/0½ iron	-	-	-	d#	-	c#	A#	G#	G#	G#	G#	G#	G#
3/0 iron	-	A#	F	f#	e	f	d	d	c#	c#	c#	c#	c#
3/0 brass	?	-	-	-	-	-	-	-	-	-	-	-	-
3/0½	-	G	B	c#'	b	c'	g	g#	g	f#	g	g	g
2/0 brass	C#	-	-	-	-	-	-	-	-	-	-	-	-
2/0 iron	-	c'	f	f#'?	f'	e'	d'	d'	c#'	c'	c#'	c'	c#'
2/0½	-	d#''	c'	?	c''	c#''	g#'	d#''	d''	d''?	d''	d''	d''
1/0	?	f'''	f''	?	f#''	f#''	g#''	d'''	d'''?	d'''?	d'''	d'''	d'''
1/0½	-	-	b'	?	c'''	d'''	g#'''	a'''	-	-	-	g#'''	g#'''
1	?	e''''	e''	?	f#'''	g#'''	c#''''	d''''	-	-	d''''	d''''	d''''
1½	-	-	a''	??	-	d#''''	-	-	-	-	-	-	-
2	?	-	c'''	-	-	-	-	-	-	-	-	-	-
2½	-	-	f'''	-	-	-	-	-	-	-	-	-	-
3	?	-	b'''	-	-	-	-	-	-	-	-	-	-
3½	-	-	e''''	-	-	-	-	-	-	-	-	-	-

Table 41

Pianos of Johann Schantz
String gauge markings

Code	Sz/4a	Sz/10	Sz/11	Sz/12	Sz/12a	Sz/14	Sz/15	Sz/16a	Sz/17	Sz/18	Sz/19	Sz/20	Sz/22
Date	c.1795	c.1815	c.1815	"1821"	c.1820	c.1820	c.1820	c.1825	c.1825	c.1825	c.1825	c.1825	c.1825
Range	FF-c''''	FF-f''''	FF-f''''	FF-f''''	FF-f''''	FF-f''''	CC-f''''	FF-f''''	FF-f''''	FF-f''''	CC-f''''	FF-f''''	FF-g''''
							75	49			22	89	17
Bridge	G/G#	G/G#	not divided	not divided	not divided	not divided	not divided	F/F#	F/F#	F/F#	F/F#	F/F#	F/F#
c'' length (mm)	287	276	276	267	275	not known*	274	268	268*	270	267	273	268
FF length (mm)	1800	1863	1815	1771	1771	not known	1774	1838	1867*	1875	1861	1903	1883
CC length (mm)							1873				1958		
CC							10/0				8/0		
CC#													
DD							9/0						
DD#											8/0 half		
EE													
FF	6/0	8/0	8/0	8/0	8/0	8/0	8/0	8/0	8/0	8/0		8/0	8/0
FF#	5/0								8/0 half	8/0 half		8/0 half	8/0 half
GG		7/0	7/0	7/0	7/0	7/0	7/0	7/0	7/0	7/0	7/0	7/0	7/0
GG#	4/0												
AA		6/0					6/0	6/0	6/0	6/0	6/0	6/0	6/0
AA#			6/0	6/0	6/0	6/0							
BB		5/0											
C							5/0	5/0	5/0	5/0	5/0	5/0	5/0
C#	2/0		5/0										
D		4/0		5/0	5/0	5/0							
D#			4/0				4/0		4/0	4/0	4/0	4/0	4/0
E								4/0					
F			3/0										
F#		4/0		5/0	5/0	5/0 half	4/0	4/0	4/0	4/0	(4/0)	4/0	4/0
G													
G#								4/0 half	4/0 half	4/0 half	4/0 half	4/0 half	4/0 half
A				5/0 half		4/0							
A#		3/0			4/0		4/0 half						
B			3/0 half	4/0									
c													
c#						4/0 half			3/0	3/0	3/0	3/0	3/0
d							3/0	3/0					
d#				4/0 half									
e					3/0								
f			2/0			3/0							
f#				3/0						3/0 half			
g		3/0 half					3/0 half		3/0 half		3/0 half	3/0 half	3/0 half
g#								3/0 half					
a													
a#													
b					3/0 half								
c'		2/0	2/0 half			3/0 half				2/0		2/0	
c#'				3/0 half					2/0		2/0		2/0
d'							2/0	2/0					
d#'													
e'													
f'			1/0		2/0	2/0							
f#'				2/0?									
g'													
g#'							2/0 half						
a'													
a#'													
b'			1/0 half										
c''					2/0 half								
c#''						2/0 half							
d''									2/0 half	2/0 half?	2/0 half	2/0 half	2/0 half
d#''		2/0 half						2/0 half					
e''			1										
f''													
f#''					1/0	1/0							
g''													
g#''							1/0						
a''			1 half										
a#''													
b''													
c'''			2		1/0 half								
c#'''													
d'''						1/0 half		1/0	1/0?	1/0?	1/0	1/0	1/0
d#'''													
e'''													
f'''		1/0	2 half										
f#'''					1								
g'''													
g#'''						1	1/0 half						
a'''								1/0 half				1/0 half	1/0 half
a#'''													
b'''			3										
c''''	3												
c#''''							1						
d''''								1			1	1	1
d#''''						1 half							
e''''		1	3 half										
f''''													
f#''''													
g''''													

Table 42

The last six in the table, Sz/16a, Sz/17, Sz/18, Sz/19, Sz/20 and Sz/22, form a group with only minor variations in the stringing schemes. Sz/11, of about 1815, is unusual in having half gauges as small as gauge $3^1/_2$. The latter gauge number, interpreted according to Thomée's Nuremberg system but interpolated with half gauges, implies wire of a diameter of 0.39mm, the same as the diameter of the strings found in the treble of the piano by Brodmann (1818) in Schloß Wörlitz. The latter instrument has gauge 3 for the top few notes with strings, presumed original, which average 0.39mm in diameter.

Followers of Stein

The pianos by Stein's followers with gauge markings include two by Wirth of c.1790 and 1803, two by Johann David Schiedmayer of 1785 and c.1795, and one by Senft of c.1795.[177] Like Stein's pianos, the range of these instruments is normally FF-f''', the thickest string gauge marked is 5/0 (at FF) and the thinnest gauge used is gauge 4 or 5, but there are exceptions. These include a piano of 1791 by the Gräbner brothers, which has gauge 4/0 at FF, gauge 6 as the thinnest gauge marked and a range of FF-g'''. One of the two pianos by Schiedmayer has gauge 6 marked as thinnest

177 The pianos by Wirth are {Munich}, 1803 and {England}, c.1790. Those by Schiedmayer are {Munich}, 1785 and Erlangen, c.1795. The piano by Senft is {Nuremberg}, c.1795.

gauge while the other has the unusual half gauge, gauge $5^1/_2$, marked as the thinnest gauge.[178]

One of the pianos by Wirth is exceptional in that the bass strings are considerably shorter than those generally found in the pianos by Stein and his school.[179] The FF string length is only 1514mm (and also marked for 5/0) whereas about 1700mm is usual.

Other instruments made by followers of Stein at the end of the eighteenth century which have gauge markings include some pianos by Johann Schmidt of Salzburg, one by Mathias Schautz of Augsburg and one by Edmund Ignaz Quernbach of Mainz.[180]

In tables 43 and 44 the gauges on the pianos of some of the followers of Stein are compared with the gauges marked on S/1788a. A piano of 1814 by C. F. Schmahl's sons is included for comparison. Schmahl was the son-in-law of Späth and Späth was one of Stein's masters. A piano by Schmahl's sons can thus be considered as made in the same tradition as those of Stein.

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178 The Gräbner piano with gauge 6 is {Italy}, 1791 and the one by Schiedmayer is {Munich}, 1785. {Erlangen}, c.1795, by Schiedmayer, has gauge $5^1/_2$ marked.

179 {Munich}.

180 The pianos by Schmidt with gauge marks are {New York}, c.1790 and {Nuremberg}, 1789. The piano by Quernbach is {Halle}, c.1795. For the gauges on the piano by Schautz ({Germany}), see Georg F. Senn, 'Der Klavierbauer Mathias Schautz (1755-1831)', *Glarena*, 46/I, 1997, 3-21.

Pianos by followers of Stein
Gauge markings

maker	Stein	Schiedmayer		Senft	Wirth	Quernbach	Gräbner	Schautz	Schmahl Söhne
code	S 1788a	Munich	Erlangen	Nuremberg	England	Halle	Italy	Germany	Nuremberg
date	1788	1785	c.1795	c.1795	c.1790	c.1795	1791	c.1795	1814
c'' (mm)	296	278*	283*	279	274	275	279*	289*	277
FF (mm)	1705	1709*	1693*	1695	1686	1739	1663*		1323
5/0 brass	FF	FF	FF	FF	FF	FF	-	FF	AA#
4/0 brass	GG	GG#	GG	GG	GG	GG	FF	GG	D
3/0 brass	AA#	BB	AA	AA	AA	AA	GG	BB	F#
2/0 brass	C#	D	C#	C	BB	C	AA#	C#	A#
2/0 iron	-	-	-	-	F	-	-	-	c#
1/0 brass	E	F	E	E	D	F	D	E	-
1/0 iron	F#	G#	?	F#	A	?	F	F#	f#
1	c	c	c	c	d	c#	c	B	a#
2	b	g	g#	a#	g#	c'	g#	f	g'
3	a#'	d'	e'	a#'	d#'	a'	f#'	f#'	f''
3½	-	-	-	-	-	-	-	-	d'''
4	f#''	g#'	a#'	g#''	b'	a#''	d''	g#''	-
5	d'''	e''	a''	-	g#''	d#'''	a''	-	-
5½	-	-	d#'''	-	-	-	-	-	-
6	-	a''		-	-	-	d'''	-	-

Table 43

Pianos by followers of Stein
Gauge markings

Maker	Stein	Senft	Schiedmayer	Schiedmayer	Wirth	Quernbach	Gräbner	Schautz	Schmahls Sohne
Code	S/1788a	Nuremberg	Munich	Erlangen	England	Halle	Italy	Germany	Nuremberg
Date	1788	c.1795	1785	c.1795	179?0	c.1795	1791	c.1795	1814
Range	FF-f'''	FF-f'''	FF-f'''	FF-f'''	FF-f'''	FF-f'''	FF-g'''	FF-f'''	FF-f'''
c'' length (mm)	296	279	297*	283*	274	295	279*	289*	277
FF length (mm)	1705	1695	1709*	1693*	1686	1548	1663*		1323
FF	5/0	5/0	5/0	5/0	5/0	5/0	4/0	5/0	
FF#									
GG	4/0	4/0		4/0	4/0	4/0	3/0	4/0	
GG#			4/0						
AA		3/0		3/0	3/0	3/0			
AA#	3/0						2/0		5/0
BB			3/0		2/0			3/0	
C		2/0				2/0			
C#	2/0			2/0				2/0	
D			2/0		0		1/0		4/0
D#				1/0					
E	1/0	1/0						1/0	
F			1/0		2/0	1/0	1/0		
F#		*Stahl*						1/0	3/0
G									
G#			*Stahl*						
A					0				
A#									2/0
B								1	
c	1	1	1	1			1		
c#						1			2/0
d					1				
d#									
e									
f								2	
f#									1/0
g			2	2					
g#					2		2		
a									
a#		2							1
b	2					2			
c'									
c#'									
d'			3						
d#				3	3				
e'									
f'									
f#'							3	3	
g'									2
g#'			4						
a'						3			
a#'	3			4					
b'		3			4				
c''									
c#''									
d''							4		
d#''									
e''			5						
f''									3
f#''	4								
g''									
g#''		4			5			4	
a''			6	5		4	5		
a#''									
b''									
c'''									
c#'''									
d'''	5						6		3 half
d#'''				5 half		5			
e'''									
f'''									
f#'''									
g'''									

Table 44

Joseph Brodmann was probably a journeyman at Hofmann's workshop the 1790's so the string gauge markings on two early pianos by Brodmann can be compared with those on similar pianos by Hofmann (tables 45 and 46).[181] The c.1800 piano by Brodmann is strung according to a scheme almost the same as the c.1800 piano by Hofmann, assuming both to have been strung with the same gauge diameters. In comparison with the c.1805 piano by Hofmann, however, the stringing of the c.1805 piano by Brodmann is heavier in the extreme bass (where the scaling is also longer) but considerably lighter for the rest of the compass. As in the pianos of Hofmann the gauge markings on both pianos by Brodmann are written along the front edge of the soundboard.

One piano of six-and-a-half octaves built by Brodmann in about 1810 also has gauge markings.[182] A repeated gauge marking indicates the change from red brass to yellow brass. The gauges start with gauge 9/0 for CC and red brass strings, presumed original, of 1.26mm in diameter. Gauge 3, from g''' to the top note f'''', has iron strings of 0.40mm in diameter.[183] These are very similar to the string diameters on another piano by Brodmann, {Wörlitz}, which has diameters of 1.27mm for 9/0 and 0.39mm for

181 {Halle}, c.1800 and {Italy}, c.1805.

182 {Vienna}.

183 The strings on {Vienna} are discussed by Alfons Huber in his article 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 193-222.

gauge 3. As Huber reports however, all the strings on the c.1810 piano by Brodmann conform to Thomée's diameters for the Nuremberg system. The intervening gauges on {Wörlitz} do not. Taken together, the diameters of all the strings on {Wörlitz}, dated 1818, give no definite evidence for Thomée's interpretation of the Nuremberg gauge system.

Another piano by Brodmann, of about 1825, has only one half gauge marking, gauge 5/0½, besides whole gauge markings. The thicknesses of the few remaining strings suggest diameters conforming to Huber's 'Berlin' system. In tables 45 and 46 the stringing scheme of the c.1825 piano by Brodmann may be compared with that of the c.1820 piano by Hofmann. Assuming that both pianos were strung using the same gauge system, we can say that in comparison to H/c.1820, the c.1825 piano by Brodmann has thicker gauges marked in the bass but is again more lightly strung in the treble. Brodmann's c.1825 piano is also distinguished by five extra notes, from CC to EE, marked for covered strings.

Of three pianos by another follower of Hofmann, Karl Benedikt, who worked in Graz at the beginning of the nineteenth century, only one has string gauges marked.[184] These begin with 7/0, as in Hofmann's pianos, and continue with the changes in similar places to the changes in Hofmann's pianos of group III (tables 45 and 46). In the bass the piano by Benedikt is in effect more heavily strung than those by Hofmann of the same period: the strings have the same thicknesses but are longer.

184 {Ptui}, c.1800.

Pianos by Brodmann and Benedickt
Gauge markings compared with those on pianos by Hofmann

Maker	Hofmann	Benedickt	Hofmann	Brodmann	Brodmann	Hofmann	Brodmann	Brodmann	Brodmann	Hofmann	Brodmann
Code	Group III	Ptui	Group IV	Halle	Italy	Group V	Vienna	Paris*	Wörlitz	Group VI	(Netherlands2)
Date	c.1795	c.1795	c.1800	c.1800	c.1805	c.1805	c.1810	1814	1818	c.1820	c.1825
Range	FF-g"'	FF-g"'	FF-g"'	FF-g"'	FF-c""	FF-c""	CC-f""	FF-f""	CC-f""	FF-f""	CC-g""
c" (mm)	av. 285	270	283	280	278	277	279*	281*	276	270	284
FF (mm)	av. 1632	1670	1631	1740	1722	1631	1743*	1755*	1745	1762	1770
wound strings	-	-	-	-	-	-	-	-	-	-	CC-EE
9/0											
red brass	-	-	-	-	-	-	CC	-	-	-	-
yellow brass	-	-	-	-	-	-	-	-	CC	-	-
8/0											
red brass	-	-	-	-	-	-	DD	-	-	-	-
yellow brass	-	-	-	-	-	-	-	-	DD	-	FF
7/0											
red brass	-	-	-	-	-	-	EE	-	-	-	-
yellow brass	FF	FF	FF	-	-	FF	FF#	-	FF#	FF	GG#
6/0											
red brass	-	-	-	-	FF	-	-		-	-	-
yellow brass	GG	GG	GG	FF	-	GG	GG#	FF	GG#	GG	BB
5/0											
red brass	-	-	-	-	GG	-	-	-	-	-	-
yellow brass	AA#	AA#	AA#	GG#	AA	AA#	AA#	GG#	AA#	AA#	D#
iron	-	-	-	-	-	-	-	-	-	-	F#
5/0½	-	-	-	-	-	-	-	-	-	-	A#
4/0 brass	D	D	D	BB	BB	D	C	BB	C	D	-
4/0 iron	F	F#	F	-	-	F	-	-	-	F#	d
4/0½	-	-	-	-	-	-	-	-	-	A#	-
3/0 brass	-	-	-	D	D	-	D	D	D#	-	-
3/0 iron	G	G#	G	?	-	G#	F	?	F	d	a#
3/0½	-	-	-	-	-	-	-	-	-	g	-
2/0 iron	c	c#	c#	A	F	d	B	A#	d	d#'	a#'
2/0½	-	-	-	-	-	-	-	-	-	-	-
1/0 iron	f#	g#	g#	d#	A	g#	g#	a	c'	b'	a#"
1/0½	-	-	-	-	-	-	-	-	-	a#"	-
1	c'	d#'	e'	a#	c'	e'	g#'	a'	d#"	e"'	a#"'
2	g#'	c"	c"	?	a#'	c"	g#"	a"	d#"'	-	d#""
3	f"	g#"	a"	a#'	d#"	a"	g#"'	a"'	d#""	-	-
4	-	-	-	c#"'	-	a"'	-	-	-	-	-

Table 45

Pianos by Benedickt and Brodmann
Gauge markings compared with those on some pianos by Hofmann

Maker	Hofmann	Benedickt	Hofmann	Brodmann	Brodmann	Hofmann	Brodmann	Brodmann	Brodmann	Hofmann	Brodmann
Code	Group III	Ptui	Group IV	Halle	Italy	Group V	Vienna	Paris*	Wörlitz	Group VI	Netherlands 2
Date	c.1795	c.1795	c.1800	c.1800	c.1805	c.1805	c.1810	1814	1818	c.1820	c.1828
Range	FF-g"'	FF-g"'	FF-g"'	FF-g"'	FF-c""	FF-c""	CC-f""	FF-f""	CC-f""	FF-f""	CC-g""
c2 length (mm)	285	270	296	280	278	277	279*	281*	276	270	284
FF length (mm)	1632 (av.)	1670	1632 (av.)	1740	1722	1631	1743*	1755*	1745	1762	1770
									1820		1879
CC							9/0		9/0		3/ 4/0
CC#											
DD							8/0		8/0		
DD#											4/ 3/0
EE							7/0				
FF	7/0	7/0	7/0	6/0	6/0	7/0		6/0		7/0	8/0
FF#							7/0		7/0		
GG	6/0	6/0	6/0		5/0	6/0				6/0	
GG#				5/0			6/0	5/0	6/0		7/0
AA					5/0						
AA#	5/0	5/0	5/0			5/0	5/0		5/0	5/0	
BB				4/0	4/0			4/0			6/0
C							4/0		4/0		
C#											
D	4/0	4/0	4/0	3/0	3/0	4/0	3/0	3/0		4/0	
D#									3/0		
E											5/0
F	4/0 weiß		4/0 weiß		2/0	4/0 weiß	3/0		3/0		
F#		4/0								4/0 weiß	5/0?
G	3/0		3/0								
G#		3/0				3/0					
A				2/0	1/0						
A#											5/0half
B							2/0	2/0			
c	2/0										
c#		2/0	2/0								
d						2/0			2/0		4/0
d#				1/0							
e											
f											
f#	1/0										
g								1/0		3/0 half	
g#		1/0	1/0			1/0	1/0				
a											
a#				1							3/0
b											
c'	1				1				1/0		
c#'											
d'											
d#'		1								2/0	
e'			1			1					
f'											
f#'											
g'											
g#'	2						1				
a'								1			
a#'				3	2						2/0?
b'										1/0	
c"		2	2			2					
c#"											
d"											
d#"									1		
e"											
f"	3										
f#"											
g"											
g#"		3					2				
a"			3			3		2			
a#"										1/0 half	1/0?
b"											
c"'											
c#"'				4							
d"'											
d#"'					3				2		
e"'										1	
f"'											
f#"'											
g"'											
g#"'							3				
a"'						4		3			
a#"'											1
b"'											
c""											
c#""											
d""											
d#""									3		2
e""											
f""											
f#""											
g""											

Table 46

None of the three known pianos by Caspar Catholnick, a follower of Walter and active at the beginning of the nineteenth century, has string gauge markings.[185] Only one piano by Rosenberger of before about 1815 has gauges marked.

At least eight pianos by Fritz, also a follower of Walter have gauges marked (tables 47 and 48). The four earliest of these instruments, all with the range FF to f'''', have no half gauge markings, begin with 7/0 for FF and end with gauge 4. The next also begins with gauge 7/0 but ends with gauge 2. Like the six-octave pianos by Walter, none of the six-octave pianos by Fritz has exactly the same stringing scheme.

Two c.1820 pianos by Fritz, of six-and-a-half octaves, CC to g'''', have half gauges marked. The stringing schemes of these two pianos are more or less the same, beginning with gauge 11/0 at CC and ending with gauge 1. The last given below, of about 1830, has heavier stringing in the treble. The lack of gauge marks for the strings of the lowest four notes in this later piano probably indicates covered strings.

The gauges marked on the pianos by Fritz placed in approximate chronological order illustrate the general trend towards heavier stringing. In his earlier six-octave pianos Fritz stamped the gauges on the wrestplank, as did Walter, a position easily accessible after or during stringing. The gauges of the three

185 {Halle}, {England} and {U.S.A.}.

later instruments are marked on the bridge, also an easily accessible position. The gauge markings on the pianos of Fritz are compared with those on two pianos by the Walter firm in tables 47 and 48.

Pianos by Johann Fritz and Michael Rosenberger Gauge markings compared with those on two pianos by the Walter firm

Code Date	F/1 c.1810	Rosenberger Krozingen	W/ c.1815f	F/2 c.1810	F/3 c.1813	F/3a 1815	F/4 c.1815	W/ c.1820	F/6 c.1820	F/7 c.1820	F/8 c.1830
Split Bridge?	F#/G	no	no	F#/G	no	no	no	no	no	no	G/G#
c" (mm) FF (mm)	278* 1729*	269 1695	287 1747	271 1713	268 1707	268 1712	270* 1711*	270* 1747*	270* 1871*	270 1875	268 1755
11/0	-	-	-	-	-	-	-	?	CC	CC	-
10/0	-	-	-	-	-	-	-	?	DD	DD#	DD#
9/0	-	-	-	?	-	-	-	?	EE	-	-
8/0	-	FF	-	-	-	-	-	?	FF	FF	FF
7/0	FF	GG	FF	FF	FF	FF	FF	?	GG#	GG	GG#
6/0	GG	AA	FF#	GG#	GG#	GG	GG	?	AA#	AA#	BB
5/0 brass	AA#	-	GG#	BB	BB	AA#	AA	?	C#	C#	D#
5/0 iron	-	C	GG#	-	-	-	-	F#	-	E	G#
5/0½	-	-	-	-	-	-	-	A#	-	-	A#
4/0 brass 4/0 iron	D -	D# -	BB -	D -	D E	C# -	C D#	- d	- A	- A	- c#
4/0½ iron	-	-	-	-	-	-	-	a#	c#	B	f
3/0 brass 3/0 iron	E G	- A#	D# -	F G	- F#	E F#	- G#	- d#'	- e	- e	- a
3/0½	-	-	-	-	-	-	-	a'	a	a	d'
2/0	A#	e	A#	A#	A#	A#	d#	d#"	d'	d'	g#'
2/0½	-	a#	-	-	-	-	-	-	g#'	a'	d#"
1/0	g	d#'	f#	f	g	g#	d'	c#'"?	f"	g"	b"
1/0½	-	g'	-	-	-	-	-	g#'"?	d"'	f"'	g"'
1	d'	b'	d#'	d#'	f#'	f#'	e'	-	b"'	d#""	d""
1½	-	e"	-	-	-	-	-	-	-	-	-
2	c"	a#"	d#"	c"	d"	e"	a"'	-	-	-	-
3	a#"	g"'	f#"'	a#"	d"'	e"'	-	-	-	-	-
4	c""	d""	c#""	a#"'	d""	d""	-	-	-	-	-

Table 47

Pianos of Michael Rosenberger and Johann Fritz
Gauge markings compared with those on pianos by the Walter firm

Maker	Fritz	Rosenberger	Walter	Fritz	Fritz	Fritz	Fritz	Walter	Fritz	Fritz	Fritz
Code	F/1	Bad Krozingen	W/c.1815f	F/2	F/3	F/3a	F/4	W/c.1820	F/6	F/7	F/8
Range	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	CC-f""	CC-g""	CC-g""	CC-g""
Date	c.1810	c.1815	c.1815	c.1810	1813	c.1815	c.1815	c.1820	c.1820	c.1820	c.1830
Bridge	split F#/G	not split	not split	split F#/G	not split	not split	not split	not split	not split	not split	split G/G#
c2	278*	269	287	271	268*	268	270*	270*	270*	270	268
FF	1729*	1695	1747	1713	1707*	1712	1711*	1747*	1871*	1875	1755
CC	-	-	-	-	-	-	-	1825*	1945*	1949	1862
CC									11/0	11/0	
CC#											
DD									10/0		
DD#										10/0	10/0
EE									9/0		
FF	7/0	8/0	7/0	7/0	7/0	7/0	7/0		8/0	8/0	8/0
FF#			6/0								
GG	6/0	7/0	5/0			6/0	6/0			7/0	
GG#				6/0	6/0				7/0		7/0
AA		6/0					5/0				
AA#	5/0					5/0			6/0	6/0	
BB			4/0	5/0	5/0						6/0
C		5/0					4/0				
C#						4/0			5/0	5/0	
D	4/0			4/0	4/0						
D#		4/0	3/0				4/0				5/0
E	3/0				3/0	3/0				5/0	
F				3/0							
F#					3/0	3/0		5/0			
G	3/0			3/0							
G#							3/0				5/0
A									4/0	4/0	
A#	2/0	3/0	2/0	2/0	2/0	2/0		5/0 half			5/0 half
B										4/0 half	
c											
c#									4/0 half		4/0
d								4/0			
d#							2/0				
e		2/0							3/0	3/0	
f				1/0							4/0 half
f#			1/0								
g	1/0				1/0						
g#						1/0					
a									3/0 half	3/0 half	3/0
a#		2/0h						4/0 half			
b											
c'											
c#'											
d'	1						1/0		2/0	2/0	3/0 half
d#'		1/0	1	1				3/0			
e'											
f'											
f#'					1	1					
g'		1/0h									
g#'									2/0 half		2/0
a'								3/0 half		2/0 half	
a#'											
b'		1									
c"	2			2							
c#"											
d"					2			2/0			
d#"			2								2/0 half
e"		1h				2	1				
f"									1/0		
f#"											
g"										1/0	
g#"											
a"											
a#"	3	2		3							
b"											1/0
c"'								1/0?			
c#"'											
d"'					3				1/0 half		
d#"'											
e"'						3					
f"'										1/0 half	
f#"'			3								
g"'		3									1/0 half
g#"'								1/0 half?			
a"'							2				
a#"'				4							
b"'									1		
c""	4										
c#""			4								
d""		4			4	4					1
d#""										1	
e""											
f""											
f#""											
g""											

Table 48

The pianos of Johann Georg Gröber, also a follower of Walter, present a similar picture to the pianos of Fritz. Of the nine instruments known to the author, all but the last are of six octaves, FF to f''''. As in the pianos by Walter and probably those of Fritz, the gauge markings appear to follow a pattern which was adjusted as each instrument was strung, especially in the treble. Gröber's string gauge markings are summarized in tables 49 and 50.

Nine pianos by Johann Georg Gröber
String gauge markings

Code date	Austria 1 c.1805	Austria 2 c.1805	New Haven c.1810	Austria 3 c.1810	Nurem-berg c.1810	Austria 4 c.1810	England c.1810	Austria 5 c.1820	Inns-bruck c.1830
c" (mm)	279*	285*	283	281*	280	272*	275	276*	273*
FF (mm)	1731*	1730*	1731	1726*	1728	1731*	1730	1730*	1733*
Range	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	FF-f""	CC-g""
Split bridge?	no	no	no	no	no	no	no	no	F/F#
7/0	FF	FF	FF	FF	FF	FF	FF	FF	FF
6/0	FF#	FF#	FF#	FF#	FF#	FF#	FF#	FF#	GG
5/0	AA	AA	AA	AA	AA	AA#	AA#	AA#	BB
4/0 brass	C	C#	C	C#	C#	-	-	D#	D#
4/0 iron	-	-	-	-	-	E	E	-	(F#)
3/0 iron	E	F	E	E	E	B	c	c	d#
2/0	A#	A#	B	A#	A#	g#	g#	c#'	e'
1/0	g	f#	g	g	g#	d#	d#	c#"	f#"
1	d#	d#	d#	d#	d#	c#"	c#"	c#"'	a"'
2	c"'	c"	c#"	c#"	c#"	b"	b"	a#"'	-
3	c#"'	a#"	d#"'	?	d#"'	a"'	a"'	-	-
4	g#"'	a"'	c#""	a#"'	c#""	-	-	-	-

Table 49

Note: {Innsbruck} has no gauges marked from CC to EE. The change to iron at F# is not marked. The present strings at F# are the first of iron.

Nine pianos by Johann Georg Gröber
String gauge markings

Code	Austria 1	Austria 2	New Haven	Austria 3	Nuremberg	Austria 4	England	Austria 5	Innsbruck
Date	c.1805	c.1805	c.1810	c.1810	c.1810	c.1810	c.1810	c.1820	c.1830
Range	FF - f""	FF - f""	FF - f""	FF - f""	FF - f""	FF - f""	FF - f""	FF - f""	CC - g""
2/3 strings	a'/a#'	a'/a#'	d'/d#'	d'/d#'	d'/d#'	d'/d#'	d'/d#'	B/c	EE/FF
Bridge	not divided	not divided	not divided	not divided	not divided	not divided	not divided	not divided	divided F/F#
c" length (mm	279*	285*	283	281*	280	272*	275	276*	273*
FF	1731*	1730*	1731	1726*	1728	1731*	1730	1730*	1733*
CC									
CC#									
DD									
DD#									
EE									
FF	7/0	7/0	(7/0)	7/0	7/0	7/0	7/0	7/0	7/0
FF#	6/0	(6/0)	7/0	6/0	6/0	6/0	6/0	6/0	
GG			(6/0)						6/0
GG#	6/0	6/0	6/0	6/0	6/0				
AA	5/0	(5/0)	(5/0)	5/0	5/0	6/0	6/0	6/0	
AA#						5/0	5/0	5/0	
BB	5/0		5/0						5/0
C	4/0	5/0	(4/0)	5/0	5/0				
C#		(4/0)		4/0	4/0				
D								5/0	
D#	4/0		4/0	4/0	4/0	5/0	5/0	4/0	4/0
E	3/0	4/0	(3/0)	3/0	3/0	4/0	4/0		
F		(3/0)							
F#									is iron
G									
G#									
A	3/0	3/0		3/0	3/0				
A#	2/0	(2/0)	3/0	2/0	2/0	4/0			
B			2/0			3/0	4/0	4/0	
c							3/0	3/0	
c#									
d									
d#									3/0
e									
f		2/0							
f#	2/0	(1/0)	2/0	2/0					
g	1/0		1/0	1/0	2/0	3/0	3/0		
g#					1/0	2/0	2/0		
a									
a#									
b									
c'								3/0	
c#'								2/0	
d'	1/0	1/0	1/0	1/0	1/0	2/0	2/0		
d#	1	(1)	1	1	1	1/0	1/0		
e'									2/0
f'									
f#'									
g'									
g#'									
a'	1								
a#'	2								
b'		1							
c"		(2)	1	1	1	1/0	1/0	2/0	
c#"			2	2	2	1	1	1/0	
d"									
d#"									
e"									
f"				?					
f#"				?					1/0
g"				?					
g#"				?					
a"		2		?					
a#"		(3)		?		1	1		
b"				?		2	2		
c"'	2			?				1/0	
c#"'	3			?				1	
d"'			2	?	2				
d#"'			3	?	3				
e"'				?					
f"'				?					
f#"'									
g"'	3								
g#"'	4	3				2	2		
a"'		(4)		3		3	3	1	1
a#"'				4				2	
b"'									
c""			3		3				
c#""			4		4				
d""									
d#""									
e""									
f""	4	4	4	4	4	3	3?	2	
f#""									
g""									

Table 50

Summary

Of the makers surveyed here, only Hofmann appears to have followed pre-determined stringing schemes rigorously while building his pianos. The other makers, to a greater or lesser degree, may have been guided by standard stringing schemes for each particular series of pianos underway, but in practice the detailed stringing appears to have been conducted according to the dictates of the ear.

Generally, inasmuch as it is possible to compare the stringing schemes of the pianos discussed here without more certain knowledge of the string diameters used, the pianos which have retained their gauge markings demonstrate the rule that the later the piano the heavier the stringing.

Within the work of each builder there appear to be no sudden changes in the stringing schemes used. This supports the idea that no distinction was made between 'systems' of string gauges. The piano makers may have thought in terms of the origin or quality of the wire they used. But from those instruments which have retained their gauge markings there is no evidence that the makers thought in terms of different systems of gauges. The evidence which there is does not contradict the idea that there was simply a system of nominal gauges each of which, in absolute terms, generally became thicker.

Two factors can be isolated which both contributed to the increase in string tension to which the pianos were subjected. The first, less consistent factor is the trend just mentioned in which the absolute diameters of the nominal gauges came to represent thicker diameters. For instance gauge 7/0 could measure 0.97mm in the eighteenth century (Thomée), 1.02mm in 1795 (Hofmann, H/c.1795c), 1.00mm in 1818 (Brodmann {Wörlitz}), 1.20mm in 1819 (Streicher, S/1819/1415), 1.14mm in about 1825 (Graf) and 1.25mm in about 1830 (Streicher's caliper). The second factor which contributed to the increase in string tension was the more or less steady trend towards using larger nominal gauges. Hofmann, for instance, used gauge 3 for c'' in 1785, gauge 2 for c'' from about 1790 to 1805 and gauge 1/0 for c'' in about 1820.

The rule that the later the piano the thicker the strings does not apply to the work of the different makers with the same consistency. If the pianos of Hofmann show the greatest uniformity, both in their stringing schemes and in the steady pattern in which the later the group of pianos the heavier the stringing, it is the pianos of Walter which show the least uniformity in both these respects.

Furthermore, it would be far from the truth to say that all builders strung their pianos according to the same or even similar stringing schemes at any particular period. The majority of the builders working at the end of the eighteenth century appear to have been influenced by Stein, whereas most of those of the beginning of the nineteenth century followed Walter, with the notable exception of Nannette Streicher who continued to preserve her father's more conservative tradition until 1805.

Walter's Viennese action appears to have been designed to enable the player to play more loudly whereas Stein's German action is more suited to soft playing. Many of the pianos built in the traditions of Stein and Walter have no gauges marked for the strings. But where there are gauge markings, the differences between these two schools of piano building are reflected in the thicknesses of the strings used by their respective members. The evidence from the surviving pianos by Stein and Walter and their followers shows that on the whole, Stein and his school, including Nannette Streicher, strung their instruments more lightly than Walter and his school already in the 1780's and probably up to about 1805. This is of course not surprising considering that a thicker string is capable of producing more volume than a thinner one.

But it is surprising to find that Hofmann, probably originally a follower of Stein rather than of Walter and generally conservative in his piano design, strung his pianos more heavily than Walter. By about 1810, the differences between the styles of the Walter firm, by then Walter and Son, and the firm founded by Stein, then led by Nannette Streicher, had largely been ironed out. But even then, in the second decade of the nineteenth century, Brodmann, as conservative in other aspects of design as Hofmann (probably Brodmann's master), appears to have maintained Hofmann's preference for heavy stringing. These overall differences between the schools are shown in tables 51 and 52.

String gauges marked on pianos by Stein and his school, Walter, Hofmann and his school

Maker	Walter	Schiedmayer	Stein	Senft	Hofmann	Hofmann	Walter	Streicher	Brodmann
date	c.1800	1785	1788	c.1795	c.1785	c.1795	c.1815	1811	c.1815
c" (mm)	278	297*	296	279	296	285	287	267	276
FF (mm)	1737	1709*	1705	1695	1632	1632	1747	1757	1745
Range	FF-g"'	FF-f"'	FF-f"'	FF-f"'	FF-f"'	FF-g"'	FF-f""	FF-f""	CC-f""
Split bridge?	no	no	no	no	no	no	no	F/F#	no
8/0	-	-	-	-	-	-	-	FF	FF
7/0	-	-	-	-	FF	FF	FF	GG	FF#
6/0	FF	-	-	-	GG	GG	FF#	AA	GG#
5/0	GG/AA#	FF	FF	FF	AA#	AA#	GG	BB	AA#
4/0 brass	C	GG#	GG	GG	D#	D#	BB	C#	C
4/0 iron	-	-	-	-	F	F	-	-	-
3/0 brass	D	BB	AA#	AA	-	-	-	D#	D#
3/0 iron	E	E	-	-	G	G	E	F#	F
2/0 brass	-	D	C#	C	-	-	-	-	-
2/0 iron	A#	B	-	-	c	c	A#	e'	d
1/0 brass	f#	F	E	E	-	-	-	-	-
1/0 iron	-	G#	?	F#	f	f#	f#	c	c'
1	d'	c	c	c	a#	c'	d#'	f"'	d#"'
2	a#'	g	c#"	b	e'	g#'	d#"	c"'	d#"
3	f#"	d'	a#'	b'	a#'	f"	f#"'	-	d#""
4	d"'	g#'	f#"	g#"	g#"	-	c#""	-	-
5	-	e"	d"'	-	-	-	-	-	-
6	-	a"	-	-	-	-	-	-	-

Table 51

Pianos by Stein, Walter and Hofmann and their followers
A comparison of gauge markings

School	WALTER	STEIN			HOFMANN		WALTER	STEIN		HOFMANN	WALTER	STEIN		HOFMANN
Maker	Walter	Schiedmayer	Stein	Senft	Hofmann	Hofmann	Walter	N. Streicher	Schmahls Söhne	Brodmann	Walter	N. Streicher	N. Streicher	Hofmann
Code	W/c.1800b	Munich	S/1788a	Nuremberg	Group I	Group III	W/c.1815f	S/1811/908	Nuremberg	Woritz	W/c.1820	S/1819/141	S/1820/155	H/c.1820
Date	c.1800	1785	1788	c.1795	c.1785	c.1795	c.1815	1811	1814	1818	c.1820	1819	1820	c.1820
Bridge split?	not split	not split	not split	not split	not split	not split	not split	F/F#	not split	not split	not split	not split	not split	not split
c2 length (mm)	278	297*	296	279	296 (av.)	285 (av.)	287	267	277	276	270*	265	272	270
FF length (mm)	1737	1709*	1705	1695	1632 (av.)	1632 (av.)	1747	1757	1323	1745	1747*	1867	1860*	1762
CC length (mm)										1820	1825*	-	-	-
Range	FF-g'''	FF-f'''	FF-f'''	FF-f'''	FF-f'''	FF-g'''	FF-f''''	FF-f''''	FF-f'''	CC-f''''	CC-f''''	FF-f''''	FF-f''''	FF-f''''
CC										9/0				
CC#														
DD										8/0				
DD#														
EE														
FF	6/0	5/0	5/0	5/0	7/0	7/0	7/0	8/0				8/0	8/0	7/0
FF#							6/0			7/0				
GG	5/0		4/0	4/0	6/0	6/0	5/0	7/0				7/0	7/0	6/0
GG#		4/0								6/0				
AA				3/0				6/0				6/0	6/0	
AA#	5/0		3/0		5/0	5/0			5/0	5/0				5/0
BB		3/0					4/0	5/0				5/0	5/0	
C	4/0			2/0						4/0				
C#			2/0					4/0				4/0		
D	3/0	2/0			4/0	4/0			4/0				4/0	4/0
D#							3/0	3/0		3/0		4/0	4/0	
E	3/0		1/0	1/0										
F		1/0			4/0 wrest	4/0 wrest				3/0				
F#				Stahl				3/0	3/0		5/0	3/0		4/0 wrest
G					3/0	3/0								
G#		Stahl												
A								2/0				2/0	3/0	
A#	2/0						2/0		2/0		5/0 half			
B														
c		1	1	1	2/0	2/0		1/0						
c#									2/0					
d										2/0	4/0			
d#														
e														
f					1/0									
f#	1/0					1/0	1/0		1/0				3/0 half	
g		2												3/0 half
g#														
a														
a#				2	1				1		4/0 half			
b			2											
c'						1				1/0			2/0	
c#'												1/0		
d'	1	3												
d#'							1				3/0			2/0
e'					2									
f'														
f#'														
g'									2					
g#'		4				2								
a'											3/0 half			
a#'	2		3		3									
b'				3				1/0 half						1/0
c''														
c#''														
d''											2/0			
d#''							2			1		1/0 half		
e''		5											2/0 half	
f''						3			3					
f#''	3		4											
g''														
g#''				4	4									
a''		6												
a#''														1/0 half
b''														
c'''											1/0?			
c#'''														
d'''	4		5						3 half					
d#'''										2				
e'''														1
f'''								1				1	1/0	
f#'''							3							
g'''														
g#'''											1/0 half?			
a'''														
a#'''														
b'''														
c''''								2				2	1	
c#''''							4							
d''''														
d#''''										3				
e''''														
f''''														
f#''''														
g''''														

Table 52

CHAPTER V

SCALING

Theoretical considerations

In the description of stringed keyboard instruments scaling is a term used to refer to the string lengths. To describe a piano as short or long scaled is to say that in general its strings are shorter or longer compared to those of other pianos. To describe the bass of a piano as short scaled in relation to the treble means that the bass strings are shorter than one might expect in relation to the lengths of the treble strings. Descriptions of scalings can thus be couched in relative terms, for instance by comparing one string length with another, or in absolute terms, for instance by giving the length of a string in millimeters. In this chapter the scalings of the pianos are examined in both relative and absolute terms.

If the material and diameter of two strings are the same but one is half the length of the other, the shorter string sounds an octave higher than the longer string under the same tension. If the string lengths of an instrument double for every fall of an octave, that instrument is said to have a 'just' or 'Pythagorean' scaling. Given the length of one string of such an instrument the lengths of the strings for all the other notes can easily be generated. Assuming equal temperament, the string lengths follow a geometric progression so that, given the string length, l_1, of one note, the string length, l_2, of the note a semitone lower is given by the formula:

$$l_2 = \sqrt[12]{2} \cdot l_1$$

The scalings of many of the pianos presented here, however, are not based on a Pythagorean scaling but on a tapered scaling, as in modern pianos. This means that although the string lengths follow a geometric progression, at least for the upper half of the compass, the octave ratio is less than 1 : 2, often 1 : 1.95. If for instance the length of the c" string is 300mm the c' string length is not 600mm but 585mm. The formula for generating the string lengths then becomes:

$$l_2 = \sqrt[12]{1.95} \cdot l_1$$

or, in general, if two strings an octave apart have lengths in the ratio 1 : R, the lengths of the strings of successive notes can be generated by the formula:

$$l_2 = \sqrt[12]{R} \cdot l_1$$

This formula gives the theoretical string lengths of a piano with a scaling designed according to a geometric progression, assuming equal temperament.

The pianos discussed here have scalings which were probably designed on the basis of a geometric progression. In practice, however, there are three factors dealt with here contributing to the deviation of string lengths from a geometric progression. First, the scaling is often interrupted by one or more gap spacers. Second, the scaling is always foreshortened in the bass and, lastly, the scaling is usually stretched in the treble.

i) Between the front edge of the wrestplank and the soundboard there is a gap, traversed by the strings and through which the hammers rise to strike. The gap tends to close, owing to the distortion of the wrestplank caused by the tension of the strings. In order to compensate for this tendency the design of almost all grand pianos built after about 1785 includes one or more small braces or so-called gap spacers. These are interposed between the front edge of the wrestplank and the bellyrail, the large transverse case member which forms the bulkhead of the inner construction and which is situated underneath the soundboard behind the action.[186]

Gap spacers, made of wood or iron, are positioned parallel to the strings across the gap. Each gap spacer is often, but not always, allotted the space in the string band normally occupied by a single choir of strings, thus creating a discontinuity in the sequence of the strings and hence in the regular progression of the string lengths. Usually the strings for the note on the bass side of the gap spacer are too long in relation to those for the note on the treble side.

186 The chief advantage of pianos with a down-striking action is that there is no gap so the wrestplank and the inner framework of the instrument can be constructed as one contiguous whole. All but a very few (S/1826/2053, S/1828/2227, S/1832/2548, S/1835/2750, S/1837/2991 and S/1839/3304) of the pianos surveyed here, however, are up-striking and have gap spacers.

ii) Bass foreshortening is the term used to refer to the shortening of the bass strings. Foreshortening usually begins in the tenor and increases towards the bass until the strings of the lowest note are about half their theoretical length.

iii) Treble stretching refers here to the lengthening of the scaling in the extreme treble. Even taking a tapered scale into account the strings of the top few notes of many pianos are longer than they should be according to the dictates of the geometric progression on which the scaling appears to be based.

A method of presenting scalings

The length of c" is useful as a single indicator of the scaling of a piano but is inadequate for a more thorough description in that its use implicitly assumes a Pythagorean scaling throughout the compass, ignoring not only bass foreshortening and treble stretching but also the possibility of a tapered scaling. In order to compare the different approaches the various makers took to designing the scalings of their pianos the following method has been employed.[187]

The c" string almost always falls within the region in which the strings more or less follow a geometric progression. The length of the string for c" of a piano can therefore be used as a reference

187 I am most grateful to Paul Poletti for suggesting this method of describing scalings and for helping me to develop the necessary computer skills to use it.

point for comparing the string lengths of that piano with the theoretical lengths the strings would have if the scaling accurately followed a geometric progression throughout the compass.

A complete set of theoretical string lengths based on the actual length of the string for c", is generated. Given the string length, l_1, of one note, the string length, l_2, of the note a semitone lower in a sequence of lengths which follow a geometric progression with an octave ratio of 1 : R is given by the formula:

$$l_2 = \sqrt[12]{R} \cdot l_1$$

The set of theoretical string lengths for a given piano generated using this formula are then compared with the actual lengths of the strings as measured by taking the ratio of the theoretical length, l_t, to the actual length, l_a. This ratio is expressed as a pitch relation, in semitones, using the following formula:

$$n = 12(\log(l_a/l_t))/\log R$$

where n is the number of semitones equivalent to the ratio $l_a : l_t$. If, for instance, the c" string length of an instrument is 284mm and if R is 2, that is, assuming an octave ratio of 1 : 2 (Pythagorean scaling), the theoretical length of the C string would be 2272mm. If the actual length of the C string is 1462mm,

$$n = 12(\log (1462/2272))/\log 2 = -7.63 \text{ semitones.}$$

The ratio of the actual length of the C string to the theoretical Pythagorean length for the C string is thus equivalent to an interval of -7.63 semitones. The negative value of n indicates that the actual length of the C string is shorter than the theoretical length; a positive value would have indicated stretching of the scaling. For the present purposes a string length will be referred to, somewhat loosely, as being a number of semitones too long or too short in relation to its theoretical length. In this case the C string is 7.63 semitones too short.

If the value of n for a piano is plotted for the complete sequence of notes, a chart is obtained of the ratios of the string lengths to those of a theoretical scaling, based on the length of the c'' string and any chosen value of R, expressed in semitones.

As examples of this method graphs 11 and 12 show the deviation of the string lengths of the piano of S/1781 from a Pythagorean scaling and from a tapered scaling with an octave ratio of 1 : 1.95. In relation to a Pythagorean scaling this instrument shows foreshortening beginning at about c'', an FF string foreshortened by $15^1/_2$ semitones and scale stretching reaching $1^1/_2$ semitones at f''' in the extreme treble. By comparison, in relation to a tapered scaling with an octave ratio of 1 : 1.95 the foreshortening begins further down the compass, at about e', the FF string is foreshortened by about 14 semitones and the scale stretching in the treble reaches just under a semitone.[188]

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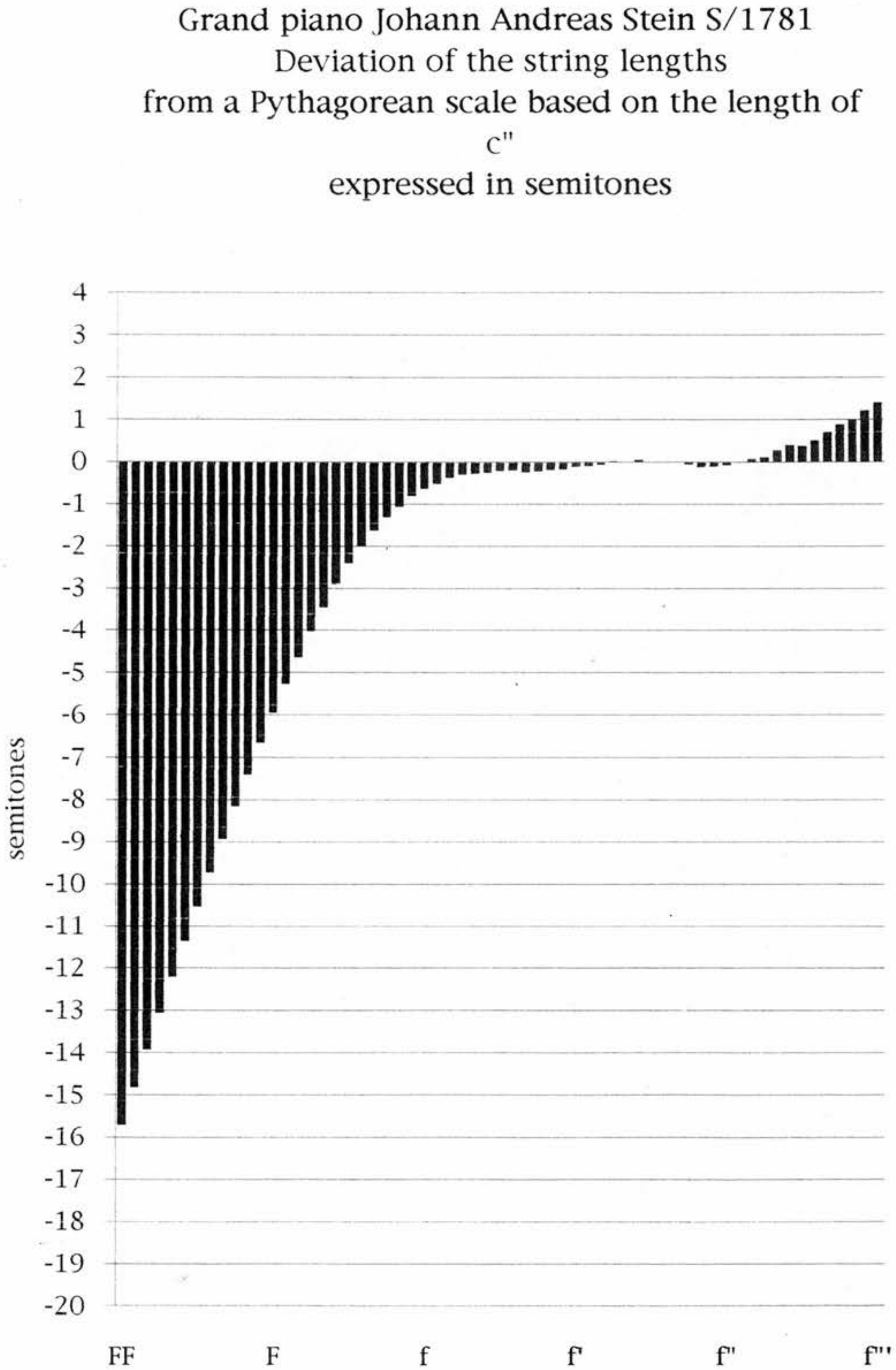
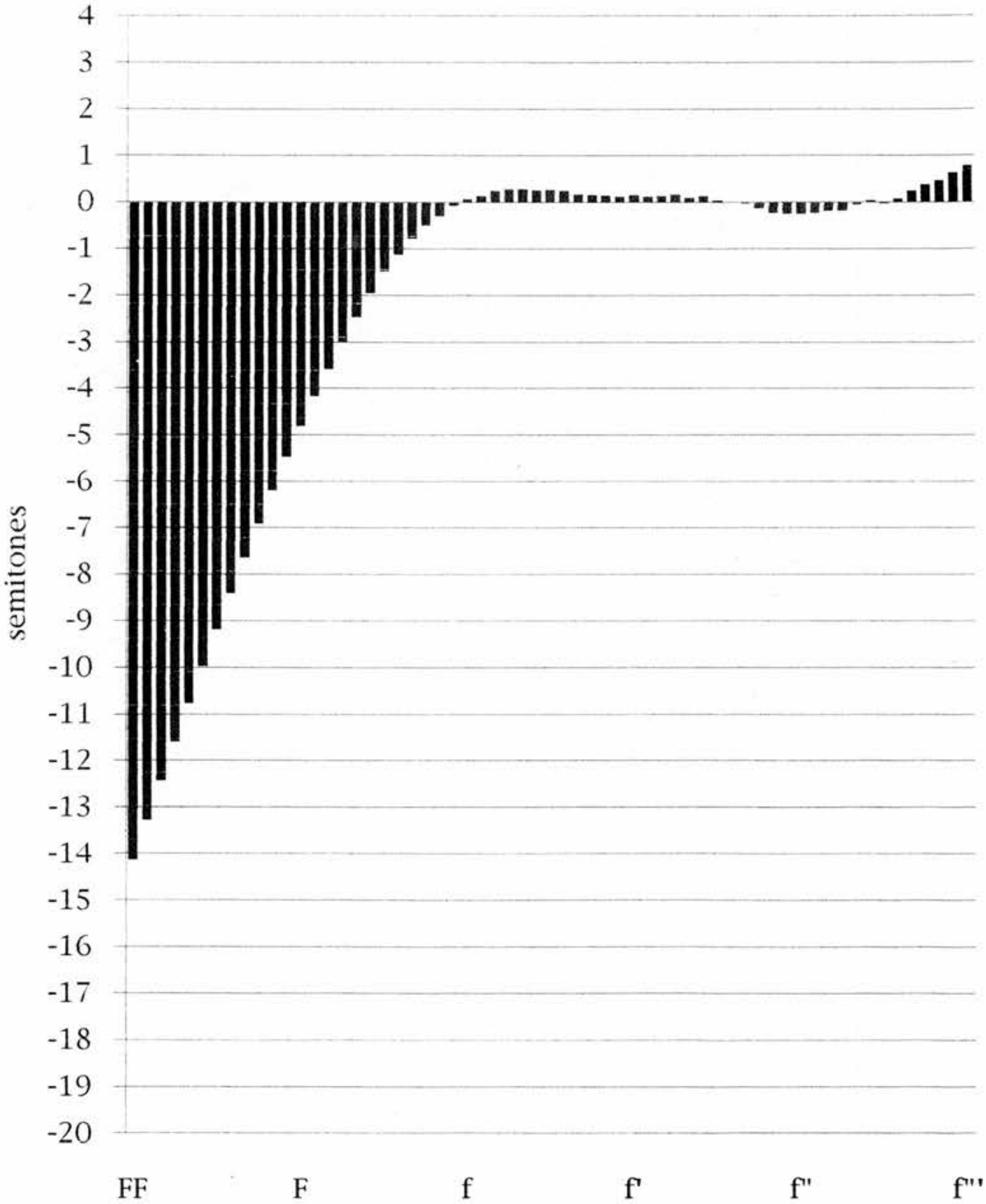
188 In the extreme treble this method of describing the scaling graphically is very sensitive. The string length for f''' in the above example is 123mm. An increase in length of only 4mm would be represented by an increase in scale stretching of more than half a semitone.


Grand piano Johann Andreas Stein S/1781
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones
semitones
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
FF
F
f
f'
f''
f'''

graph 11

Grand piano Johann Andreas Stein S/1781
Deviation of the string lengths
from a cuve based on the length of c''
and an octave ratio of 1 : 1.95 expressed in
semitones



graph 12

Pythagorean scaling in contemporary written sources

In the eighteenth and early nineteenth centuries there was of course an awareness of the idea of Pythagorean scaling. In the long essay on the improvement of keyboard instruments published in Carl Friedrich Cramer's *Magazin der Musik* under the initials 'J. B. v. H.' in 1784, the author makes use of the rule that frequency is inversely proportional to length.[189] J. B. v. H. also argues, however, that the intervening notes should not have lengths adjusted according to equal temperament but according to Kirnberger's temperament. The task is

> 'To find the shape of the bridge on a *Clavier* by determining the lengths of the strings according to the temperament of Kirnberger'.[190]

This is done by using logarithms and the inverse rule to convert the exact frequencies defined by Kirnberger's temperament into string lengths. Using the octave ratio of 1 : 2, in other words assuming Pythagorean scaling, one can extrapolate to find all the string lengths for five octaves from FF to f'''.

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189 J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 277-298.

190 '*Aufgabe. Nach der Kirnbergerschen Temparatur, die Figur eines Stegs auf einem Clavier durch die Längen der Saiten zu bestimmen.*' J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 281.

> 'One finds the string lengths for the remaining notes by doubling or halving according to whether they are an octave deeper or higher.'[191]

J. B. v. H. gives a complete set of string lengths calculated in this way in his 'Table 1'. In his 'Table 2' he gives another set of string lengths calculated according to equal temperament. For both temperaments he arrives at an FF string of more than four meters long, that is, with no foreshortening. But, he admits, few instruments are long enough for strings of this length and goes on to use a rule of thumb to foreshorten the bass strings. The string lengths are exactly calculated according to the inverse rule down as far as the note c. But then from B to FF J. B. v. H simply adds 8 lines (*Linien* or twelfths of an inch) to each previous string length to generate each successive length.[192] In his tables 3 and 4 he thus arrives at a string length of 1370mm for the note FF, considerably shorter than found on any surviving grand piano but longer than found on any square piano of the period. In two further tables the lengths are calculated according to the inverse rule down to the note F. Thereafter each successive note is obtained by adding a fixed increment of 12 lines to the length of the previous note. This produces a length of 2392mm for the note FF, this time far longer

191 '*Die Saitenlängen für die übrigen Töne findet man durch Verdoppelung oder Halbirung der gefundenen, je nachdem solche eine Octave tiefer oder höher sind.*' J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 283.

192 Tables 3 and 4. J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 300.

than found on any surviving grand piano.[193] This method of foreshortening, in which the sequences of lengths for the bass strings strictly follow an arithmetic progression, contrasts starkly with the detailed calculations used for minutely matching the treble scaling to Kirnberger's temperament.

Although the scalings calculated by J. B. v. H. were probably never realised in practice it is of importance here to note the use of the formula relating string tension, frequency, density, length and diameter alongside the Pythagorean principle in 1784.

Two other theoreticians also mention the use of the Pythagorean principle in scaling design. In his *Stimmbuch* of 1804, J. H. C. Nachersberg wrote that

> 'The scaling is nothing other than the measure for the strings; it determines their lengths. Parallel lines are drawn on the soundboard and the scaling is arranged along them, and, according to the positions of the keys [*Tangenten* - tangents?], the lengths of the measured strings marked off on them, e.g. for c''' 5, for c'' 10, for c' 20 inches [*Zoll*].[194]

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193 Tables 5 and 6. J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 301-2.

194 '*Die Mensur ist nichts anders, als der Maß-stab für die Saiten; sie bestimmt ihre Längen. Auf dem Resonanzboden werden Parallellinien gezogen und auf diese vermittelt der Mensur, und zwar von den Stellen der Tangenten aus, die abgemessenen Längen der Saiten notirt, z.B., für c''' 5, für c'' 10, für c' 20 Zoll* [...]'. J. H. C. Nachersberg, *Stimmbuch, oder vielmehr: Anweisung, wie jeder Liebhaber sein Clavierinstrument, sey es übrigens ein Saiten- oder Pfeifenwerk, selbst repariren und also auch stimmen könne*, 2nd. ed, Breslau und Leipzig, 1804, 147. The passage in question is repeated verbatim in *Clavier- Stimmbuch oder deutliche Anweizung wie jeder Musikfreund sein Clavier-Flügel, Forte-piano und Flügel-Fortepiano selbst stimmen, repariren, und bestmöglichst erhalen könne*, published by Gall, Vienna 1805, on p.95.

In his handbook of 1817 C. F. G. Thon remarks that

> 'to raise the note an octave at the same tension the length must be halved.'[195]

Neither J. B. v. H., nor Nachersberg nor Thon were piano makers so it is unlikely that they would have had first hand experience in designing the scaling of an instrument; their theoretical ideas have the character of armchair philosophy. In practice a Pythagorean scaling found only limited use in southern German and Viennese piano design.

Tapered scalings in contemporary theory: Jakob Bleyer

Jakob Bleyer, in his announcement in the *Allgemeine musikalische Zeitung* of 1811, advocated the use of a tapered scaling, that is, a scaling which follows a geometric progression but according to an octave ratio of less than 1 : 2.

> 'Through an accurately conducted experiment, for which we had to make two of our own pieces of equipment and a monochord, the length, the thickness of the strings and the most advantageous tension for the notes f'''' and little f were determined. From these notes the remaining 47 intervening notes, which should show a geometric

195 '[...] *den Ton um eine Octave zu erhöhen, daher bei gleiche Spannng die Länge um die Hälfte kleiner seyn muß.*' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 49.

progression, were generated. This gave us our proportion for the octave equal to 1 : 1.9458608.'[196]

It would of course be impossible to achieve this accuracy in practice. Nevertheless, Bleyer clearly believed that the scaling should follow a geometric progression and that the geometric progression should be determined by experiment and calculation.

Bleyer may have expounded one rule in his writings, however, while using another in practice. The string lengths of an upright grand piano by him, built after his announcement of 1811 had appeared, more closely approach a Pythagorean scaling than a scaling with an octave ratio of 1 : 1.9458608.[197] In table 53 the lengths of the strings for each C and F are compared with their theoretical lengths calculated according to a Pythagorean scaling and also according to a scaling using Bleyer's octave ratio. It appears to be more likely that Bleyer used the Pythagorean ratio when designing the scaling of this particular piano.

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196 '*Durch einen genau angestellten Versuch, wozu zwey eigene Apparate und ein Einsaiter verfertigt werden mussten, wurde die Länge, die Dicke der Saiten und die vorteilhafteste Spannung für die Töne f'''' und klein f bestimmt. - Aus diesen Tönen wurden die übrigen einzuschaltenden 47 Töne, welche eine geometrische Reihe bilden müssen, entwickelt, und hieraus ergab sich unser Octaven-Verhältnis = 1 : 1.9458608.*' *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung*, No. XVII, Leipzig, November, 1811,75.

197 {Budapest}.

An upright grand piano Jakob Bleyer {Budapest}
The measured string lengths compared with the theoretical lengths generated using an octave ratio of 1 : 2 and an octave ratio of 1: 1.9458608, both based on the length of c''

Note	Measured length (mm)	Theoretical length 8ve ratio 1 : 2 (mm)	Theoretical length 8ve ratio 1 : 1.9458608 (mm)
FF	1699	3260	2955
C	1463	2176	2044
F	1358	1630	1519
c	1030	1088	1030
f	814	815	780
c'	539	544	529
f'	401	408	401
c''	272	272	272
f''	205	204	206
c'''	136	136	140
f'''	101	102	106
c''''	67	67	72
f''''	49	51	54

Table 53

Tapered scalings in practice

In practice, most makers appear to have based their designs on a geometric progression. A number of them, however, including Stein, seem to have used an octave ratio of 1 : 1.95 rather than 1 : 2. Whether simply by drawing on traditional knowledge based on experience or whether by proceeding from some theoretical point of view makers had been using an octave ratio of 1 : 1.95 long before Bleyer's claim of 1811 that the octave ratio should not be 1 : 2 but 1 : 1.9458608. Bleyer again appears to be rationalising traditional practice by using 'scientific' principles.

An octave ratio of 1 : 1.95 amounts in practice to two octaves containing not 24 Pythagorean semitones but 23. The actual length given, for instance, to c''' is the theoretical length of the string for b'' calculated according to a Pythagorean scaling. If the c' string is 582mm long the note c''' is assigned the theoretical Pythagorean length for the note b'', 154mm. Stein's piano of 1782 (S/1782) has a c' string length of 582mm and the string for the note c''' is indeed 154mm. Stein, and other makers who appear to have used the octave ratio of 1 : 1.95, simply had to design their scalings such that two octaves contained 23 Pythagorean semitones rather than 24 in order to achieve the same tapered scaling advocated by Bleyer. The scalings of a selection of pianos are now presented to illustrate the use or rejection of the tapered scale. For the sake of simplicity pianos have been chosen without gap spacers.

Stein's use of the tapered scaling

The harpsichords of the two *vis-à-vis* instruments and all eight of the pianos by Stein without a gap spacer have scalings which more closely approximate a tapered scaling with an octave ratio of 1 : 1.95 than a Pythagorean scaling with a ratio of 1 : 2.[198] The scaling of one such piano was given in graphs 11 and 12 and the scaling of another is presented in graphs 13 and 14. The string lengths of only eight semitones conform to the octave ratio 1 : 2 while a full two octaves conform to the ratio 1 : 1.95. The other seven pianos and the two harpsichords without gap spacers have similar scalings and in each case the scalings are best accounted for by the same ratio, 1 : 1.95.

Schiedmayer's rejection of the tapered scaling

The surviving pianos by Schiedmayer have carefully chosen scalings, evidenced by the remarkable similarity amongst them. One is presented in graph 15. There is little doubt that Schiedmayer based his scaling design on an octave ratio of 1 : 2 and thus appears to have rejected the tapered scale apparently preferred by his master Stein.

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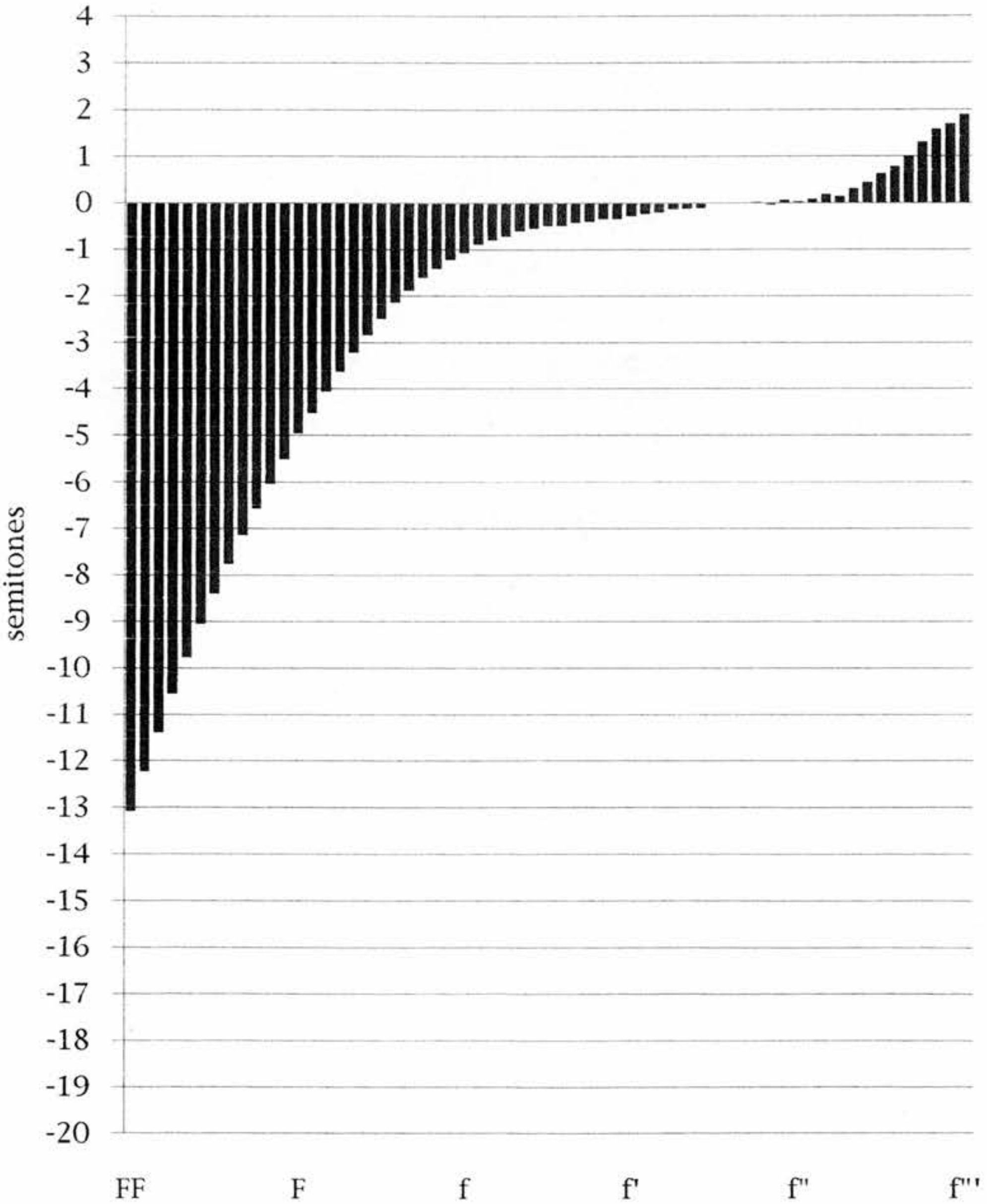
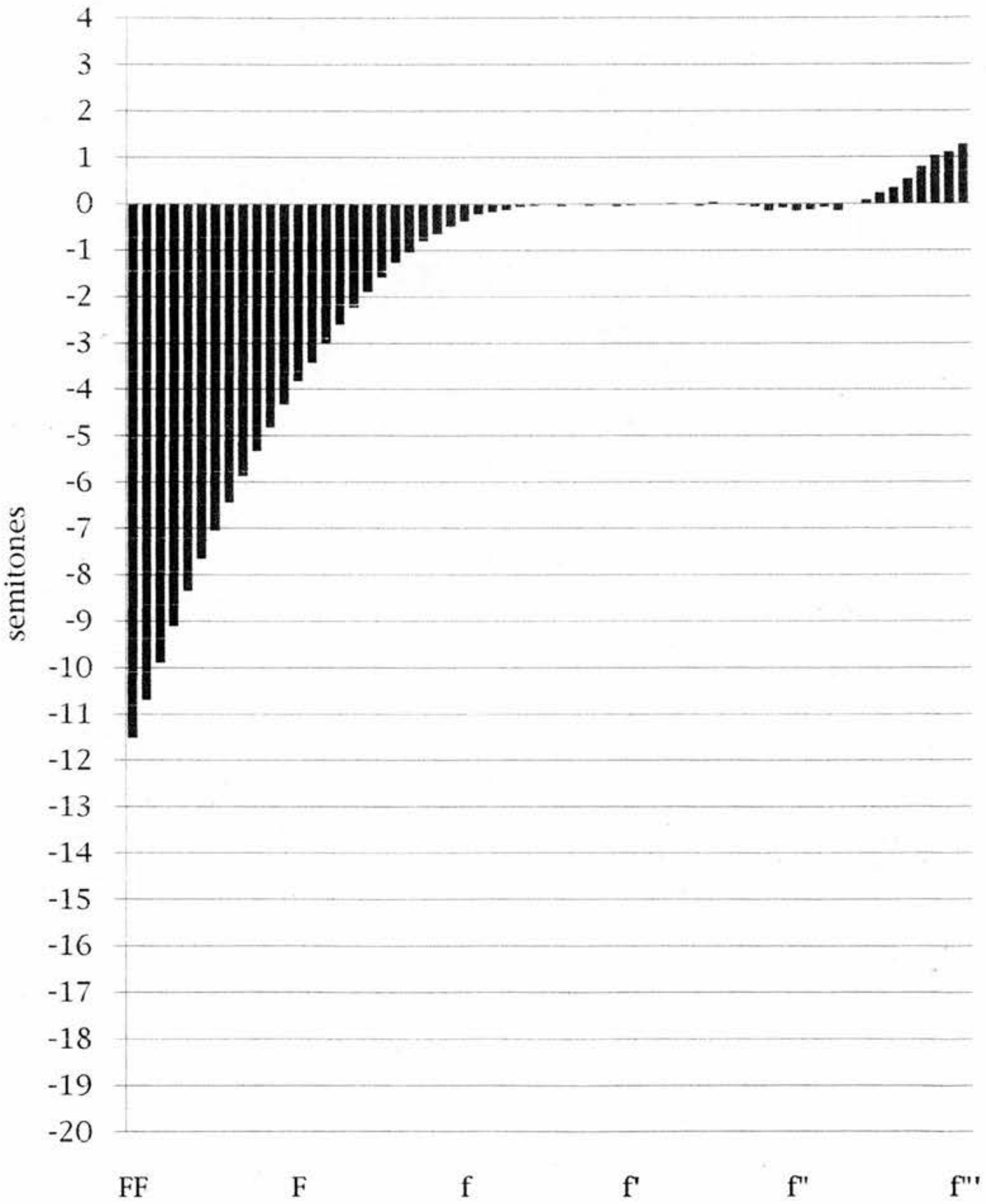
198 These are S/1777 (both the 8' harpsichord scaling and the piano scaling), S/1781 (the piano of the claviorganum), S/1782, S/1783a, S/1783b, S/1783c, S/1783d (both the 8' of the harpsichord and the piano) and S/1784. The gap spacer now in S/1781 is, in the author's opinion, a later addition.

Grand piano Johann Andreas Stein S/1783a
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



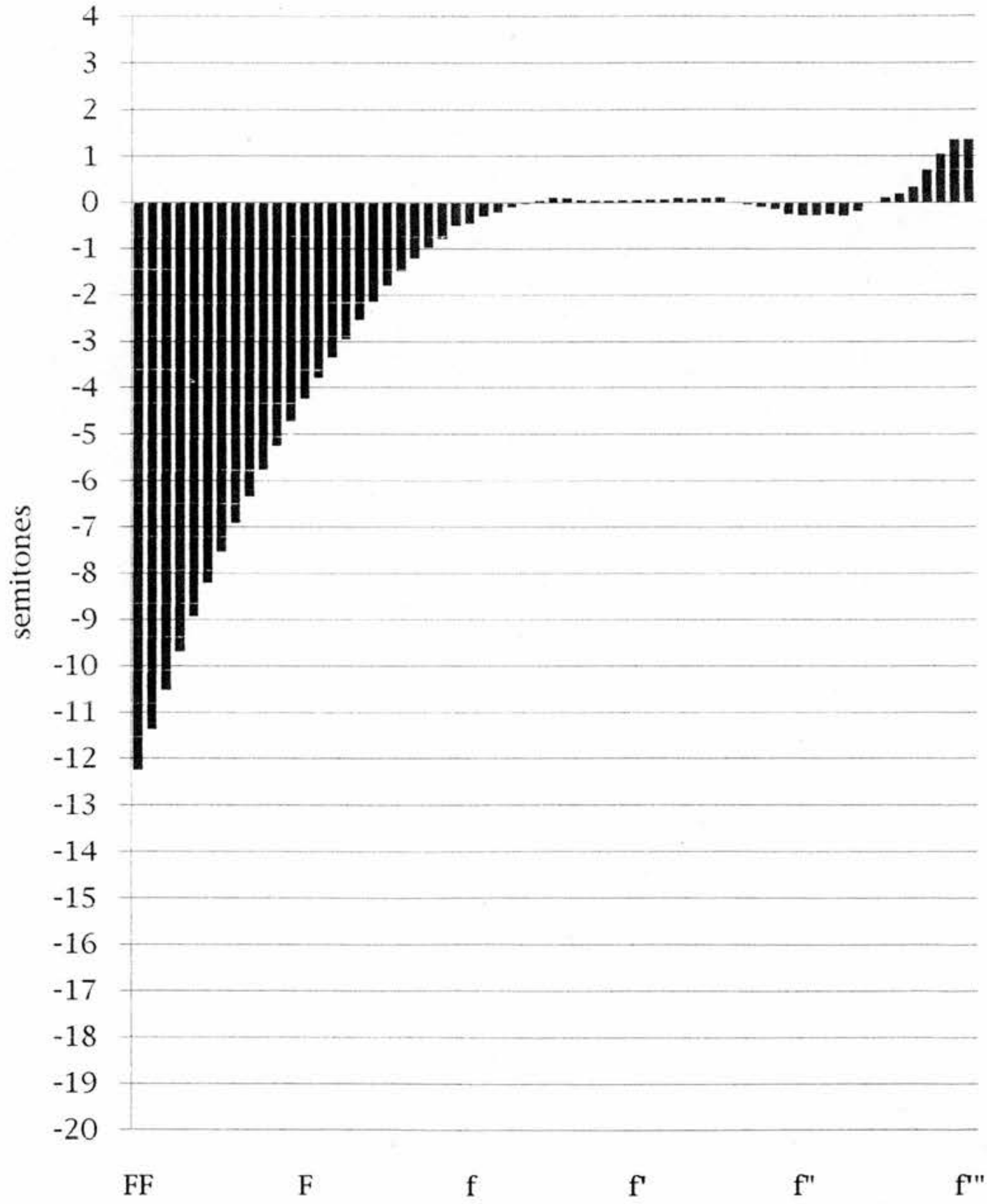
graph 13

Grand piano Johann Andreas Stein S/1783a
Deviation of the string lengths
from a cuve based on the length of c''
and an octave ratio of 1 : 1.95 expressed in
semitones



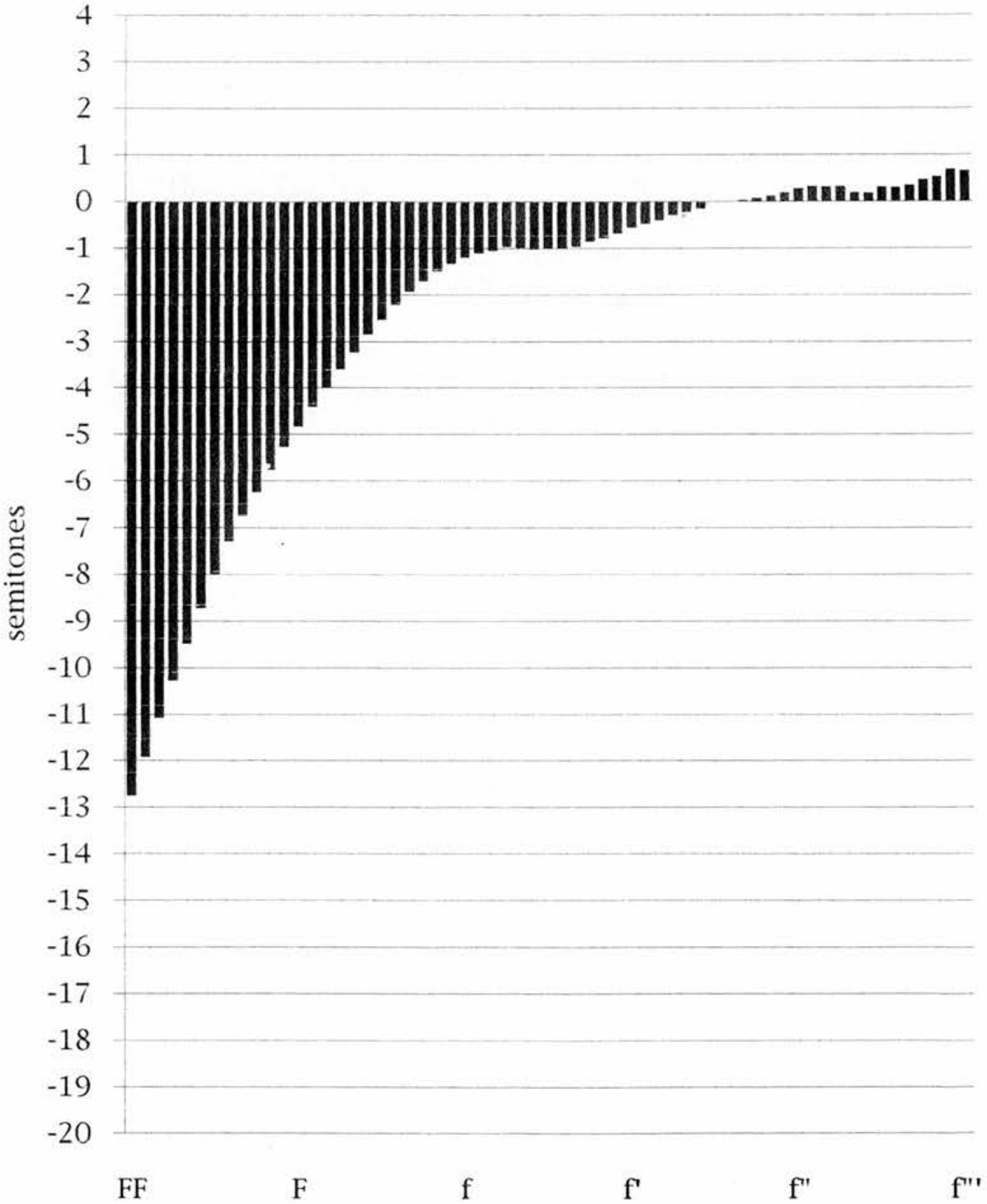
graph 14

Grand Piano Johann David Schiedmayer 1801
{Germany 1}
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



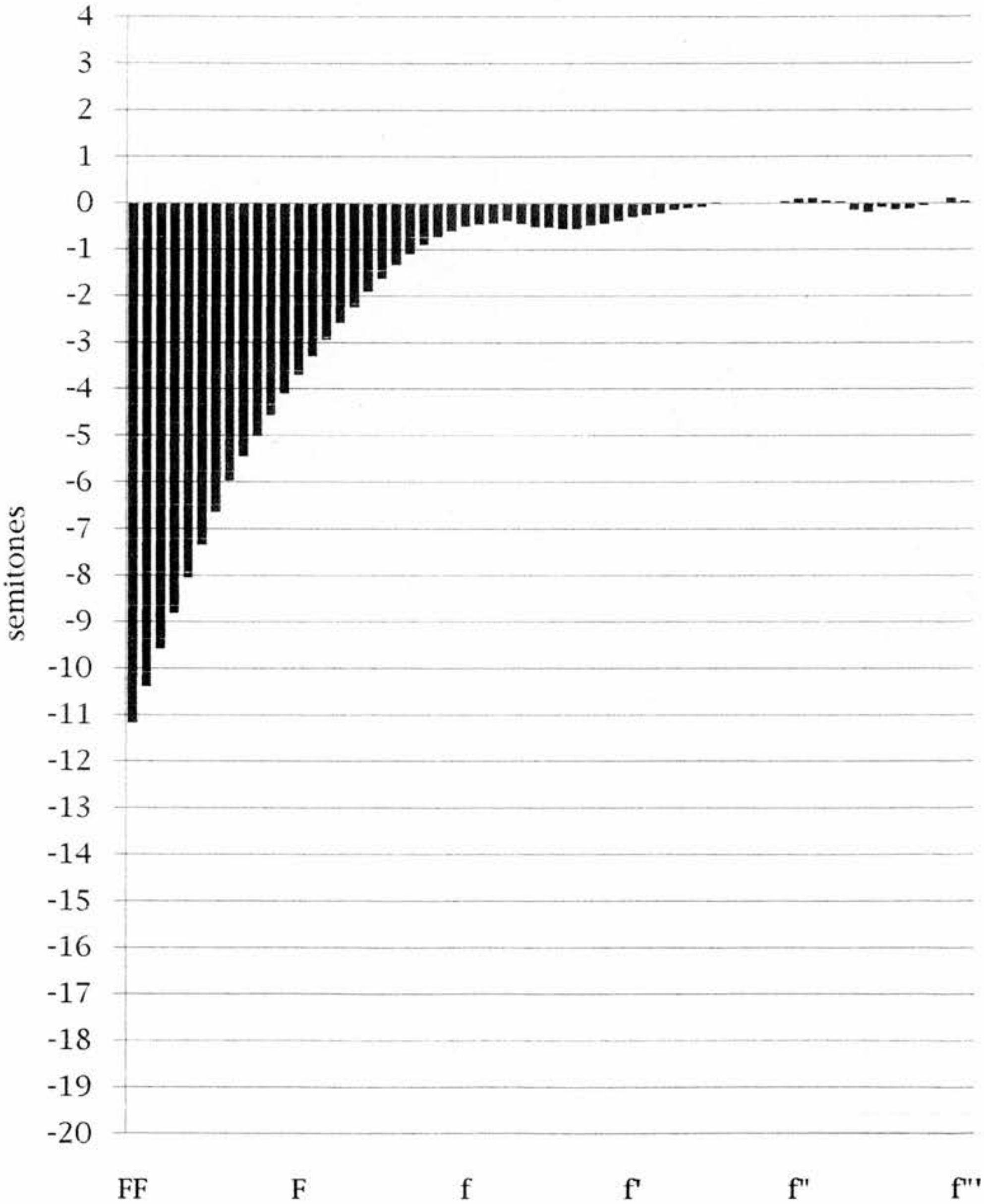
graph 15

Grand Piano Ignatz Kober {Braunau}
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 16

Grand Piano Ignatz Kober {Braunau}
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 17

Kober's use of the tapered scaling

The three surviving pianos of Ignatz Kober have nearly identical scalings which also more closely approximate a tapered scaling with an octave ratio of 1 : 1.95 than Pythagorean scaling (graphs 16 and 17).

Table 54 compares the scalings of the three pianos by Kober. The averages of the string lengths for the f's and c's of the three are given in mm and in Viennese *Zoll*, and compared with their theoretical Pythagorean lengths based on the average length for f'. The scaling appears to have been conceived on Pythagorean principles starting with a 16 *Zoll* f' string length. The f string is 32 *Zoll* long and the FF string is 64 *Zoll* long, thus achieving a foreshortening in the bass of 12 semitones. In the treble half of the compass, however, the scaling is tapered, using an octave ratio of about 1 : 1.95.

Three grand pianos Ignatz Kober
The averaged measured string lengths in mm and Zoll
compared with the theoretical lengths generated using
an octave ratio of 1 : 2 from the average length of f'

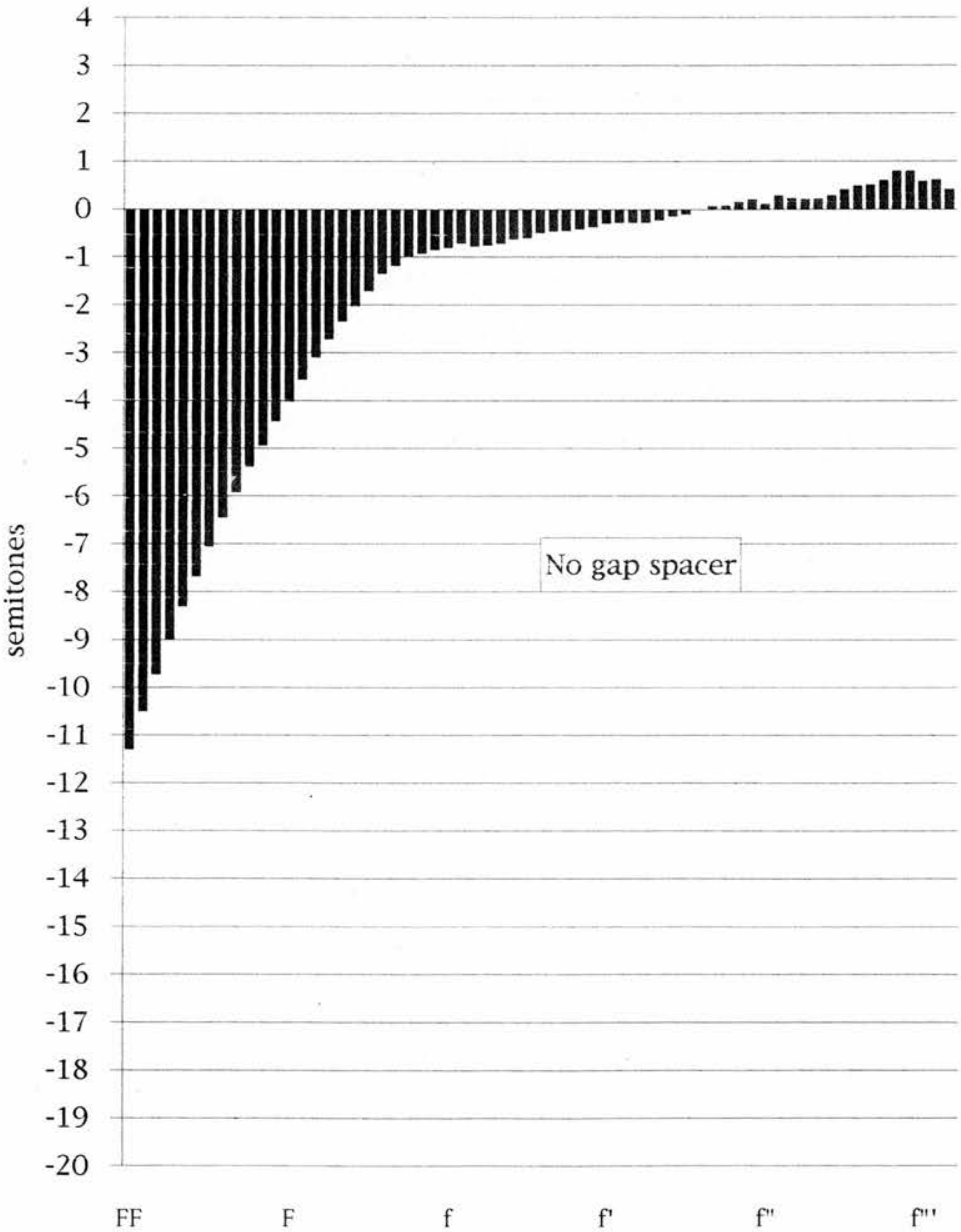
Note	{Vienna 1}	{Braunau}	{Prague}	Average length mm	Average length *Zoll*	Pythagorean equivalent mm	Pythagorean equivalent *Zoll*
FF	1687	1681	1687	1685	64.02	3384	128.58
C	1543	1537	1540	1540	58.51	2259	85.82
F	1333	1326	1327	1328	58.48	1692	64.29
c	1036	1028	1025	1030	39.12	1129	42.91
f	823	816	820	820	31.14	846	32.14
c'	555	550	557	554	21.05	564	21.45
f'	424	422	424	423	16.07	423	16.07
c''	295	291	291	292	11.11	282	10.73
f''	223	221	221	221	8.42	212	8.04
c'''	149	148	151	150	5.67	141	5.36
f'''	112	113	115	113	4.31	106	4.02

Table 54

Schantz's use of the tapered scaling

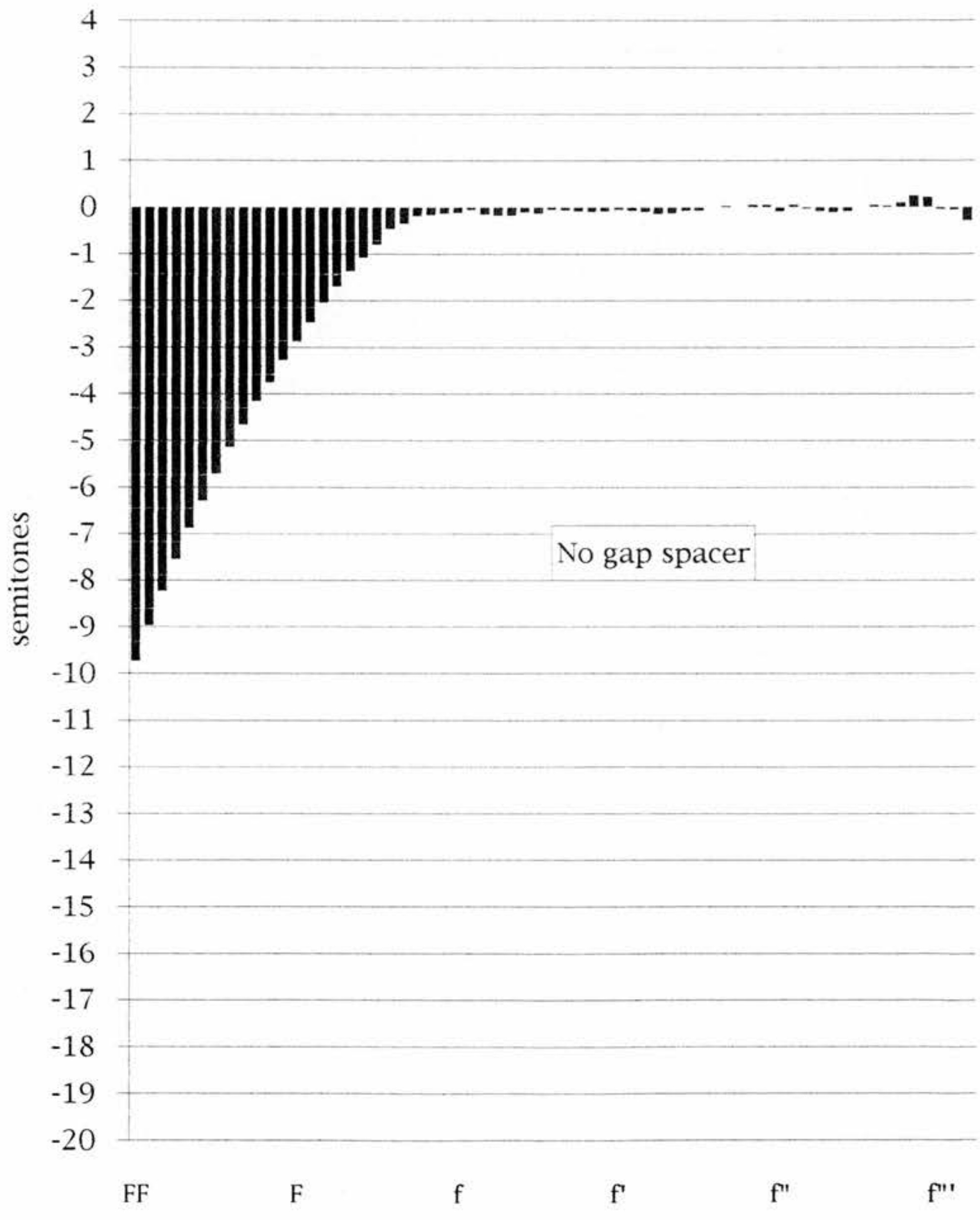
The use of tapered scaling with an octave ratio of 1 : 1.95 is especially clear in the early pianos made by Schantz. In about 1815 he appears to have changed to Pythagorean scaling. The scalings of some of his pianos without gap spacers are given in graphs 18, 19, 20, 21 and 22.

Grand Piano Johann Schantz (Sz/2) c.1790
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



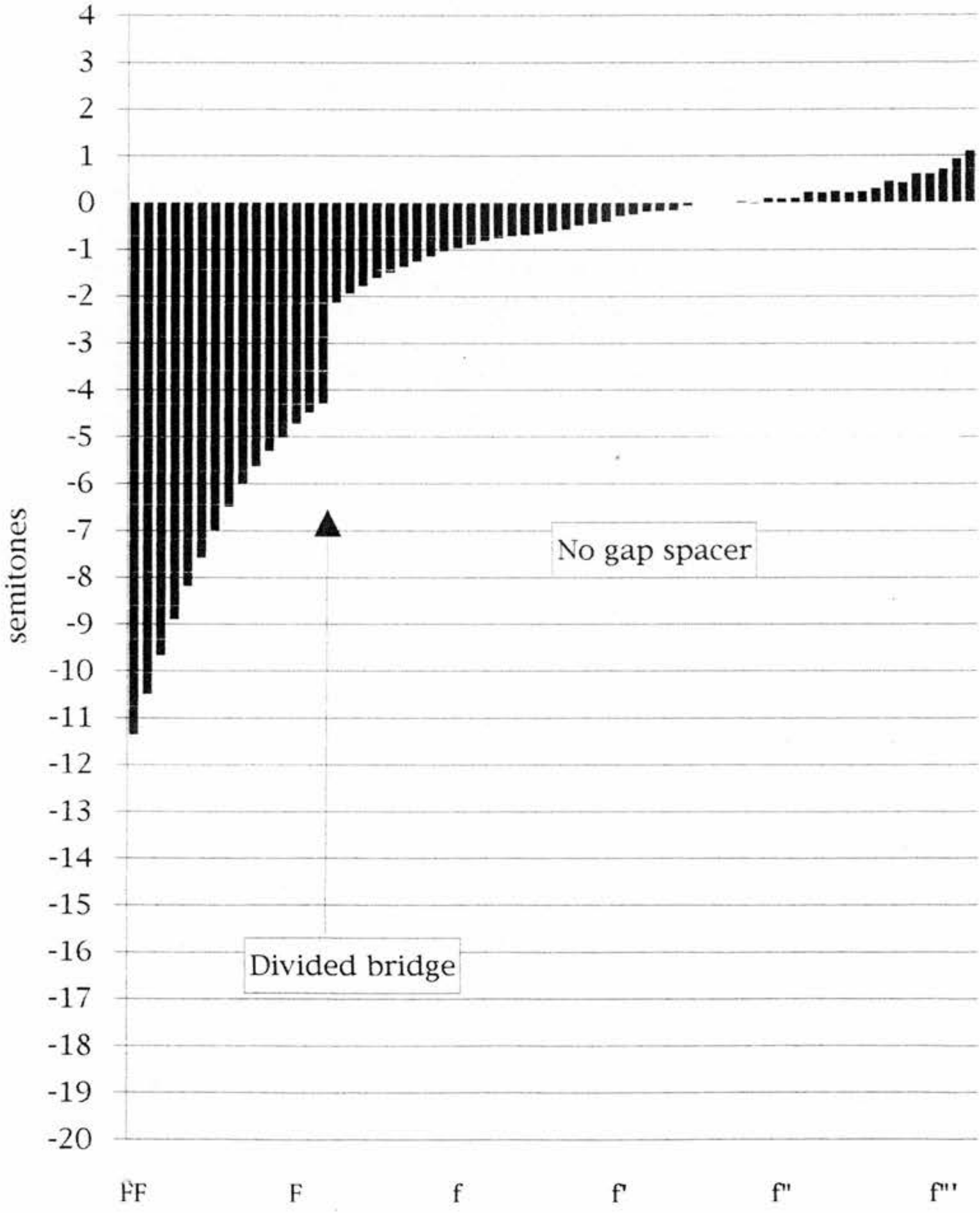
graph 18

Grand Piano Johann Schantz (Sz/2) c.1790
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



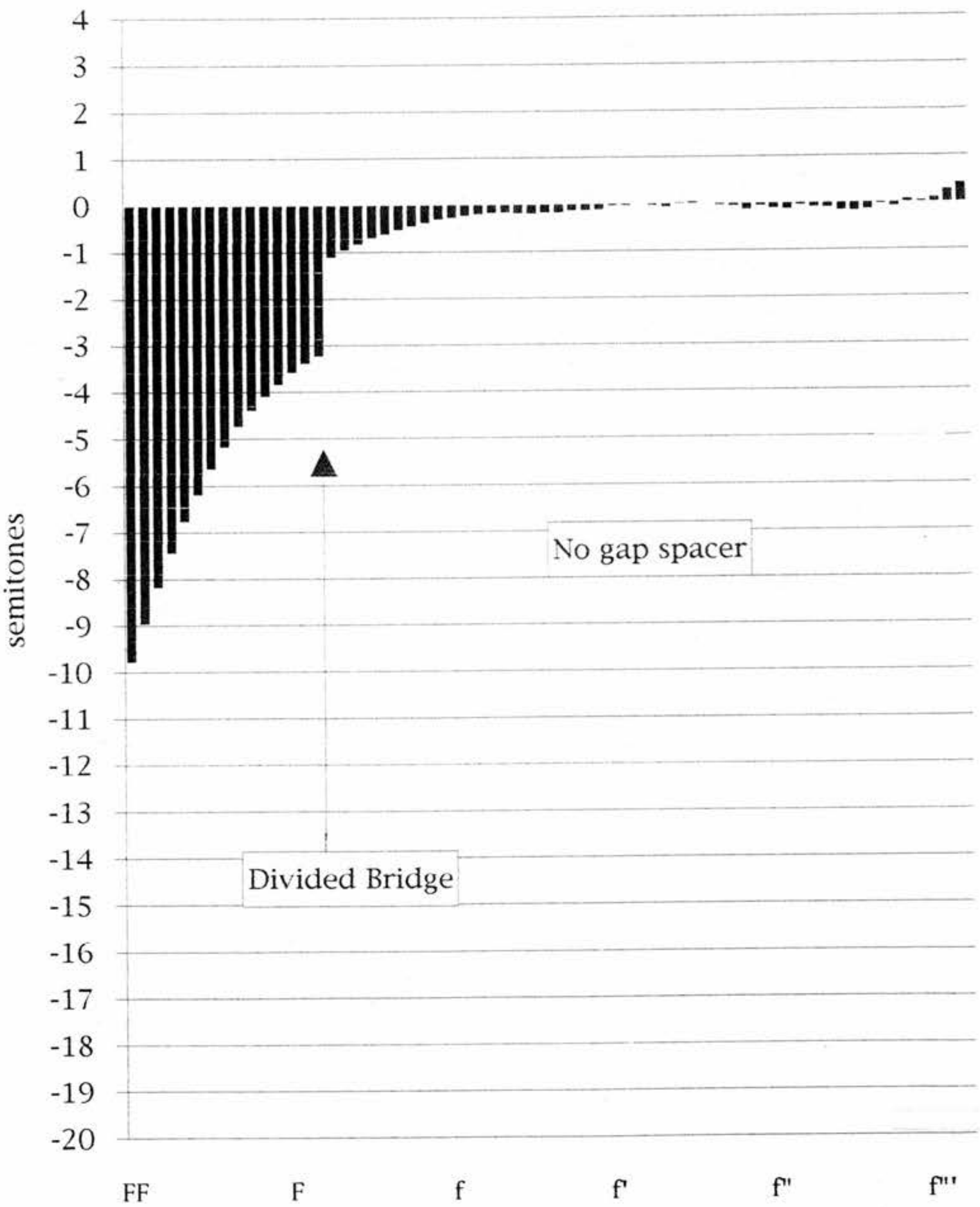
graph 19

Grand Piano Johann Schantz (Sz/3) c.1795
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



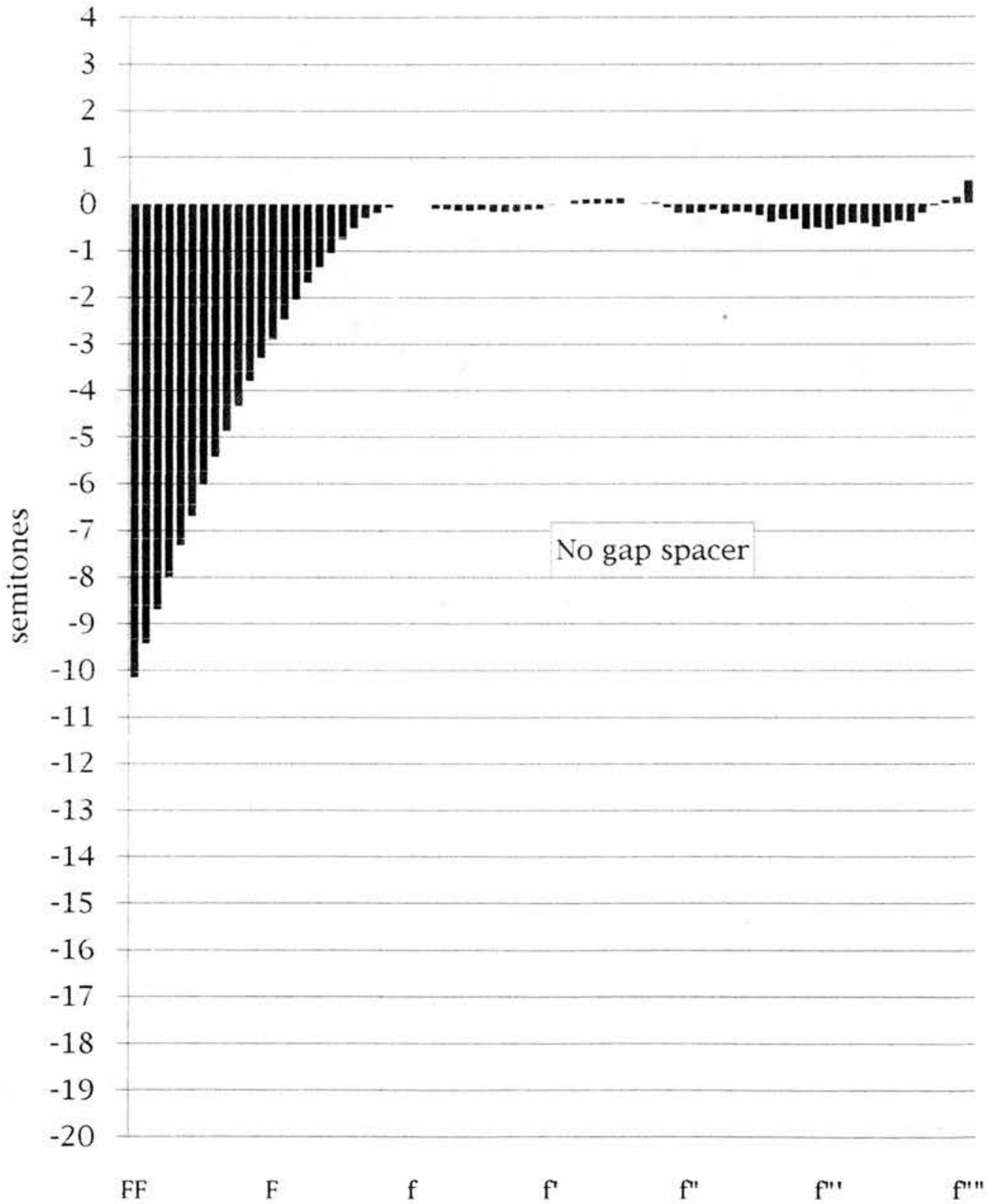
graph 20

Grand Piano Johann Schantz (Sz/3) c.1795
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 21

Grand Piano Johann Schantz c.1820 Sz/13
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 22

The scalings of Hofmann's pianos, with the exception of H/c.1820, do not accurately follow a geometric progression, showing irregularities in the treble which cannot be neglected (graphs 23 and 24). There are also instruments by other makers with scalings which do not convincingly follow a geometric progression. These include pianos by Walter and at least two of the surviving *Tangentenflügel* of the firm Späth *und* Schmahl and of Schmahl when he worked alone after his father-in-law's death. Other instruments by these two builders with string lengths which do approach a geometric progression follow a wide variety of octave ratios, ranging from 1 : 1.88 to 1 : 1.92.[199] Such builders as Hofmann, Späth and Schmahl may have used a geometric progression as a starting point for their scaling designs but in practice appear to have tolerated greater deviations than other makers.

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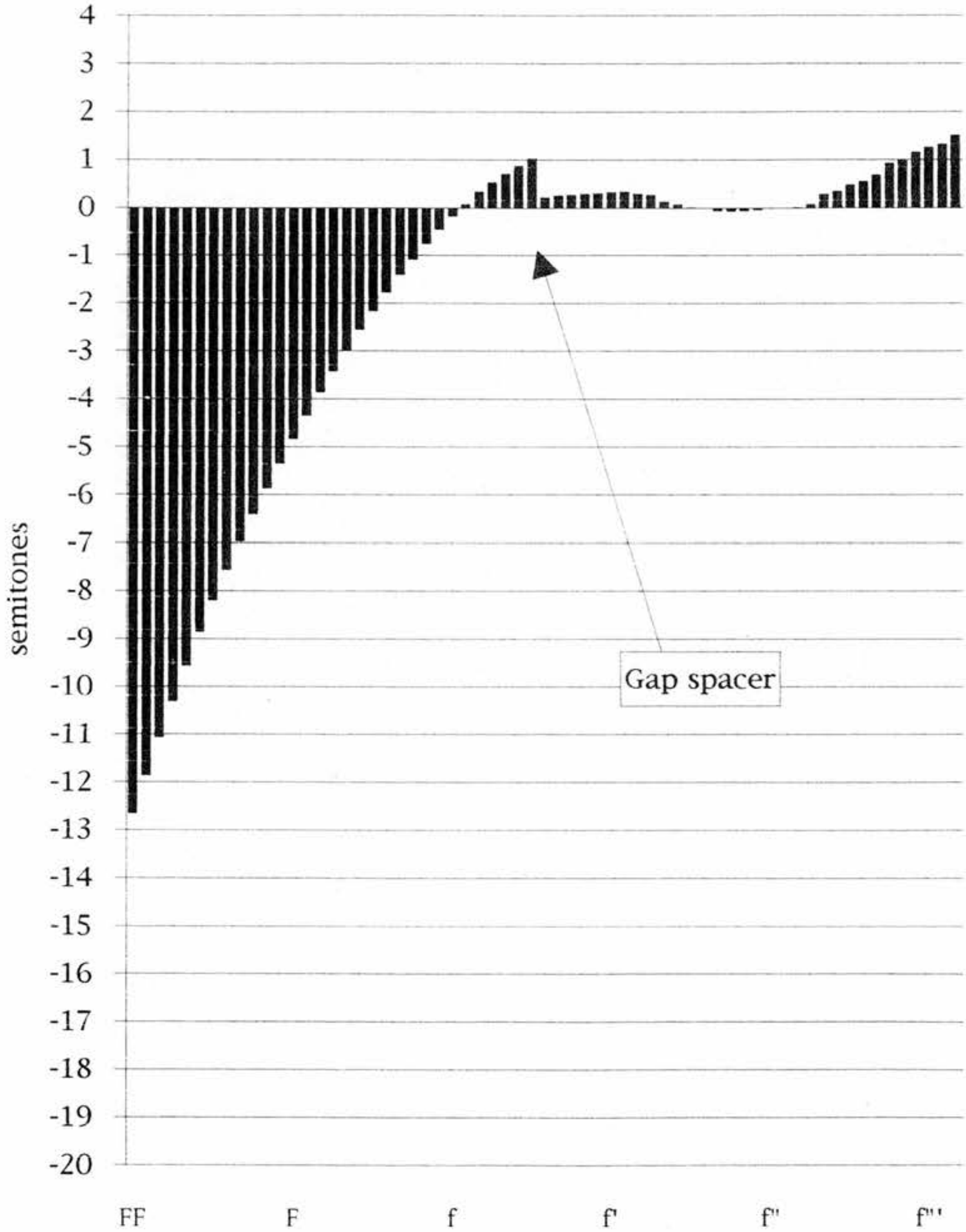
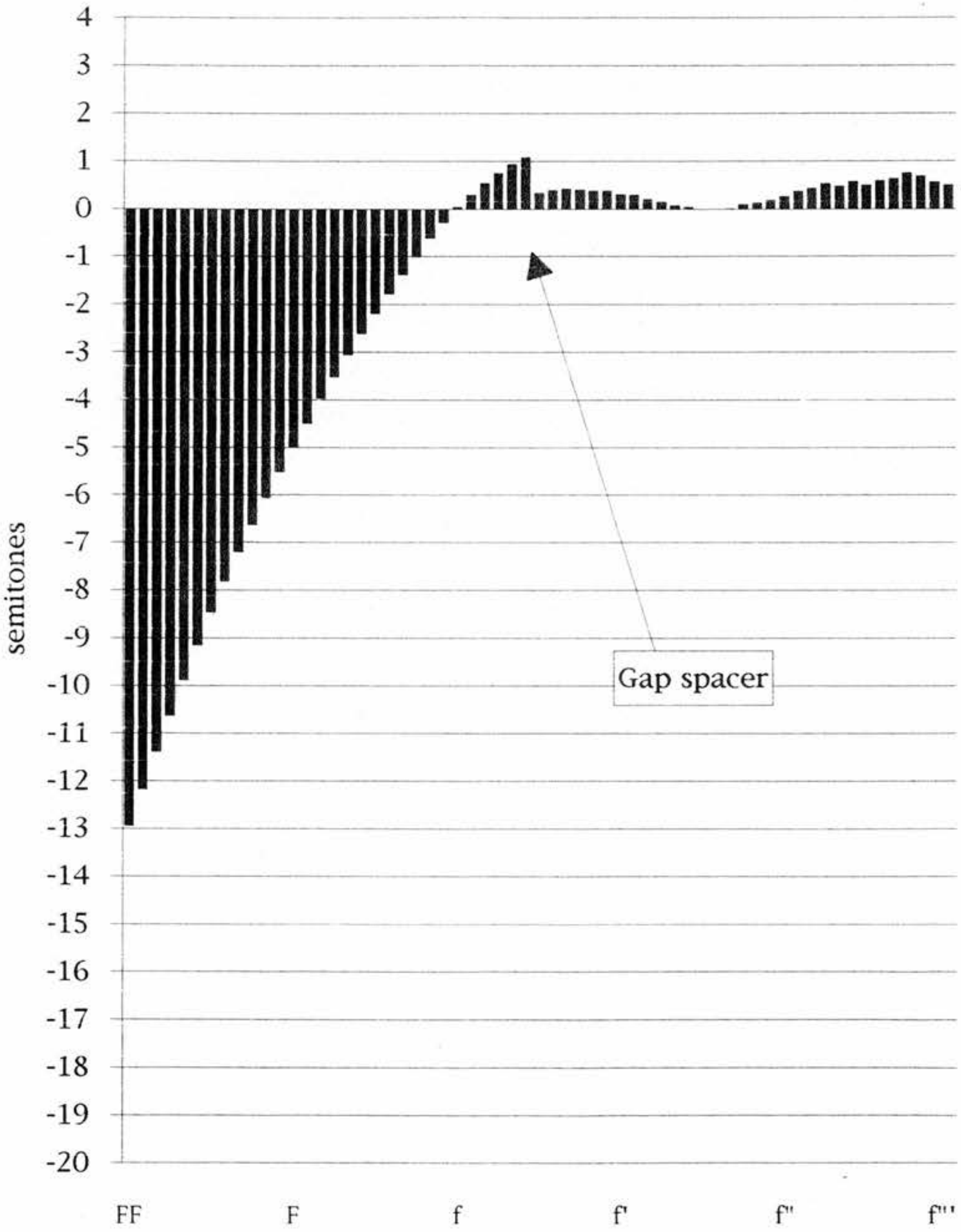
199 The scaling of the *Tangentenflügel* by Späth *und* Schmahl {Halle}, c. 1785 does not follow a geometric progression; that of the *Tangentenflügel* by Späth *und* Schmahl {South Dakota}, 1789 has an octave ratio of 1 : 1.92; that of the *Tangentenflügel* by Schmahl {Leipzig}, 1790 has an octave ratio of 1 : 1.88; that of the *Tangentenflügel* by Schmahl {The Hague}, 1791 has an octave ratio of 1 : 1.92; that of the *Tangentenflügel* by Schmahl {Nuremberg}, 1794 does not follow a geometric progression.

Grand Piano Ferdinand Hofmann (H/1795a)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



graph 23

Grand Piano Ferdinand Hofmann (H/1790b)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



graph 24

The commonly occurring deviations in the scaling from a geometric progression are now each discussed in turn. These deviations reflect the presence of one or more gap spacers, bass foreshortening and treble stretching.

Scaling and the gap spacer

There are only a few pianos built in the Viennese and southern German traditions after about 1785 without one or more gap spacers. These exceptional instruments include:

1) all the known pianos (1784-1801) by Schiedmayer;

2) the earlier pianos by Könnicke, those of c. 1795 and those dated 1796;

3) a six-octave piano by C. F. Schmahl of 1809;[200]

4) the two earliest pianos by Schantz, of about 1790 and 1795, and one later piano by him of about 1820;[201]

5) some pianos made by Brodmann between about 1805 and 1815.[202]

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200 {Nuremberg 2}.

201 Sz/2, Sz/3 and Sz/13.

202 {Austria} and {Halle} have a gap spacer. {Italy} c.1805, {Vienna} c. 1810 and {Paris} 1814 have no gap spacer while {Netherlands 1} c.1815, {Wörlitz} 1818 and {Netherlands 2} c.1825 all have a gap spacer. It may be that Brodmann built pianos with and without gap spacers during the same period. Both pianos by him in the Berlin Musikinstrumenten-Museum (Inv. Nos. 312 and 4073) have gap spacers. One of these is documented as the one to which Weber referred in a letter of April 16th 1813 to his brother. Weber wrote '*Ich habe 2 herrliche Instrumente gekauft eins von Streicher und eins von Brodmann. An Einem Tage habe ich gewiß 50 verschiedene gesehen von Schanz, Walter, Wachtl u. die alle nicht einen Schuß Pulver*

Wooden gap spacers, used for instance by Stein and Hofmann, are usually of oak or sycamore and about 8mm to 10mm thick. They run from the wrestplank to the bellyrail, parallel to the strings and under them. The iron gap spacers, used for instance by Walter and Schantz, vary between 4mm and 8mm in thickness. They also run parallel to the strings, in some cases arching up over the strings and in other cases running under the strings. The advantage of the arching gap spacers is that they do not have to take up any extra space in the string band and thus cause no discontinuity in the scaling pattern. Arching gap spacers also facilitate the incorporation of a *una corda* stop. A gap spacer between the hammers can prevent the shifting of the action, certainly in pianos in which the space allotted to the gap spacer is kept to a minimum. Nannette Streicher experimented with the arching gap spacer in one exceptional instrument, S/1805/649. Through the use of the arching gap spacers in this piano the string lengths can follow an uninterrupted geometric progression from f to c'''' (graph 25).

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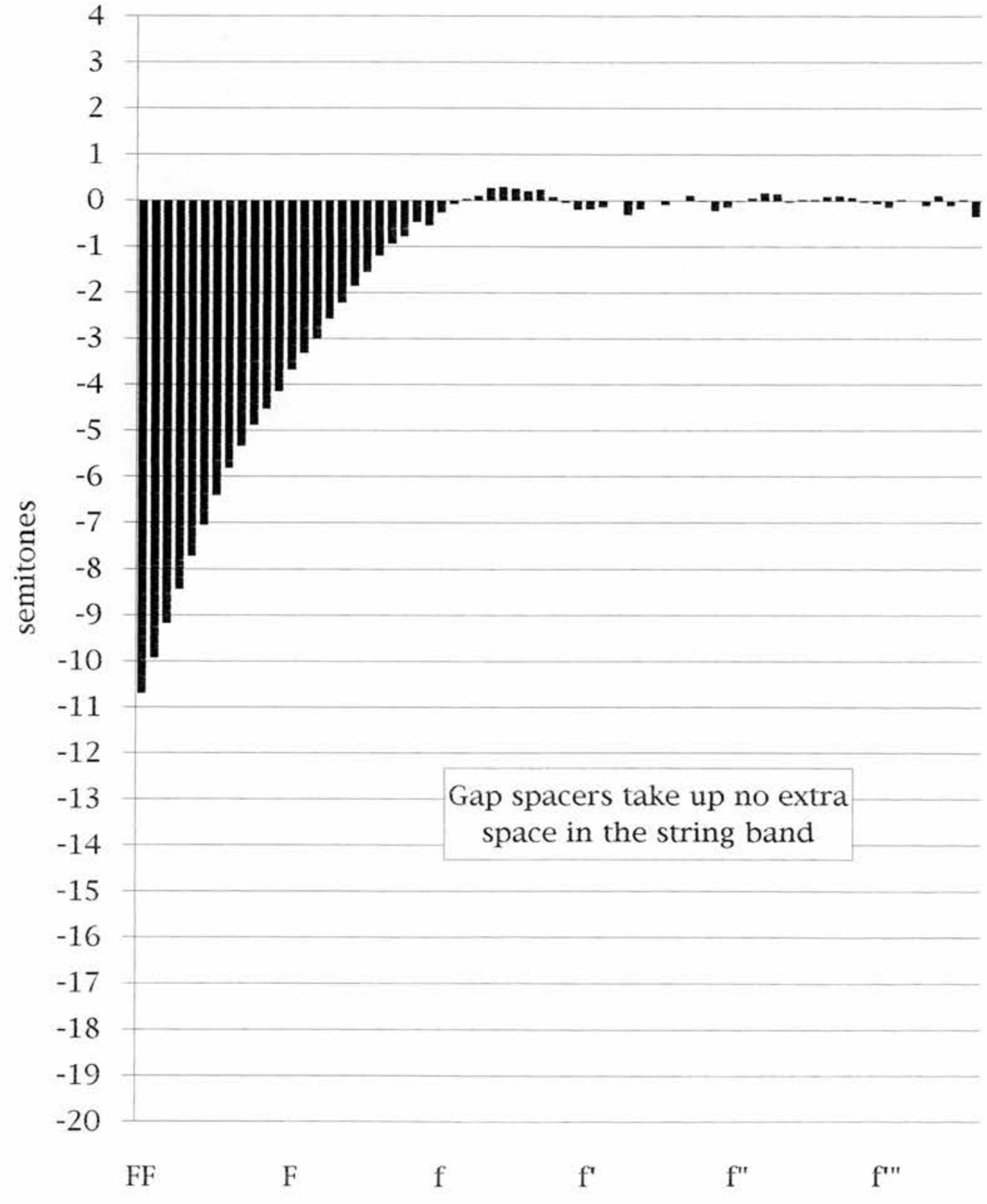
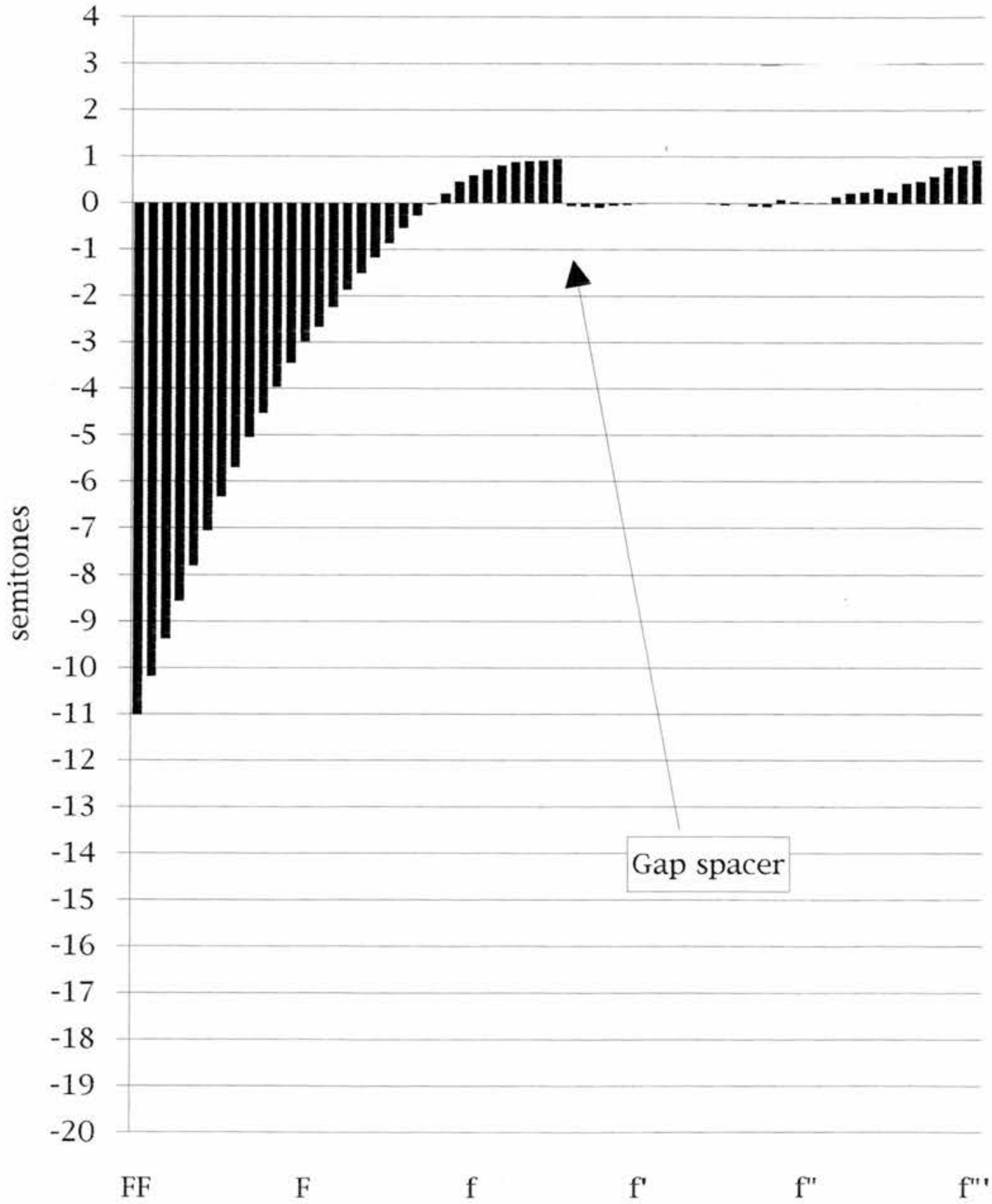
taugen im Vergleich von jenen.' ['I have bought two magnificent instruments, one by Streicher and one by Brodmann. In one day I have certainly seen 50 different ones by Schanz, Walter, Wachtl etc. all of which are not worth powder and shot by comparison.'] Quoted in Ludwig Nohl, *Musiker-Briefe. Eine Sammlung Briefe von C. W. von Gluck, Ph. E. Bach, Jos. Haydn, Carl Maria von Weber und Felix Mendelsohn-Bartholdy. Nach den Originalen veröffentlicht von Ludwig Nohl.* Leipzig 1867, 224. If indeed the instrument in Berlin is the same and that Weber bought it new from Brodmann then this instrument, with a gap spacer, was made in 1813, between the c.1810 piano {Vienna} and the 1814 piano {Paris}, neither of which has a gap spacer.

Grand Piano Nannette Streicher S/1805/649
Deviation of the string lengths
from a curve based on the length of c''
and an octave ratio of 1 : 1.95 expressed in
semitones



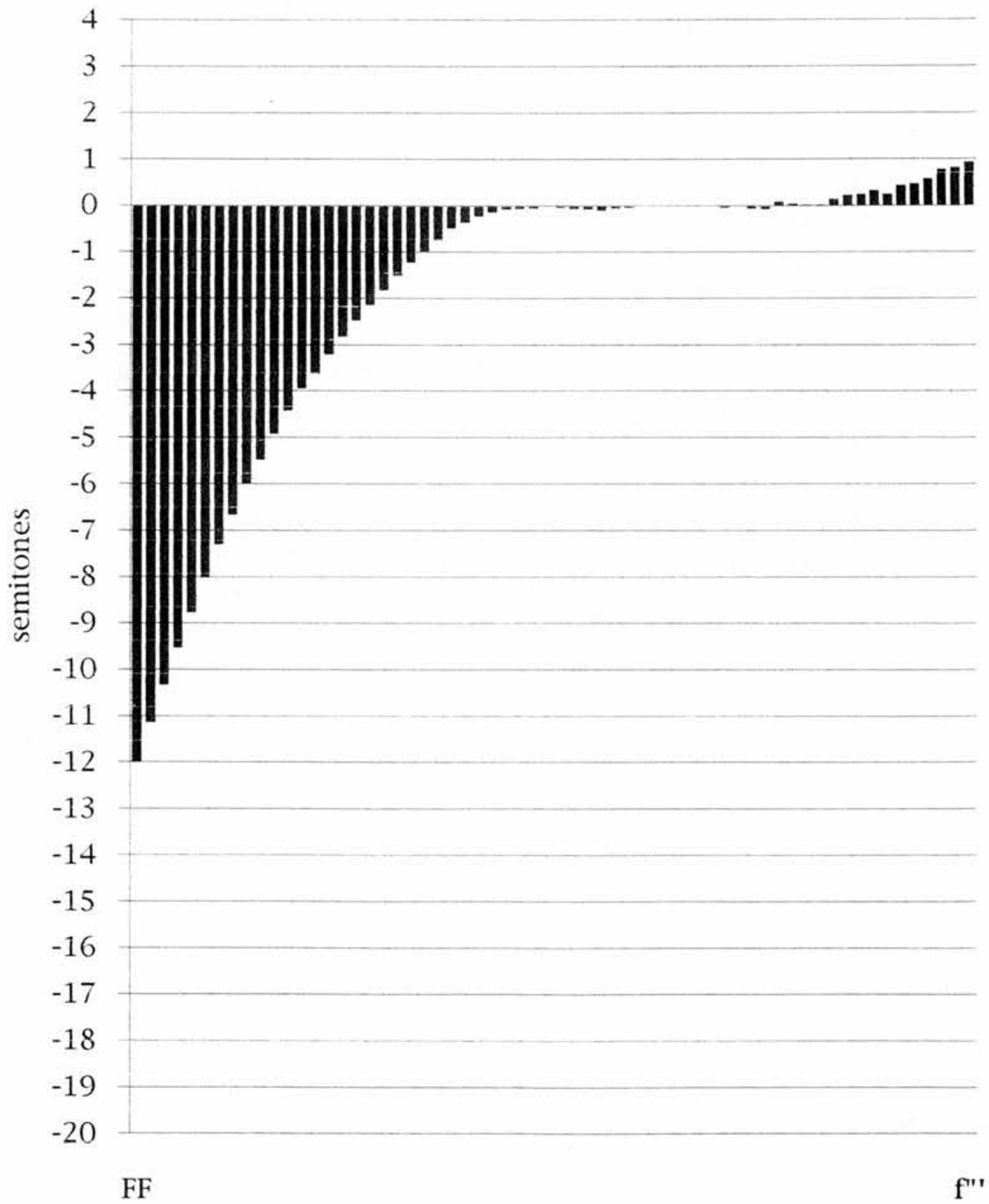
graph 25

Grand piano Johann Andreas Stein S/1783e
Deviation of the string lengths
from a curve based on the length of c''
and an octave ratio of 1 : 1.95 expressed in
semitones



graph 26

Grand Piano Johann Andreas Stein S/1783e
Deviation of the curve of the bridge
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones

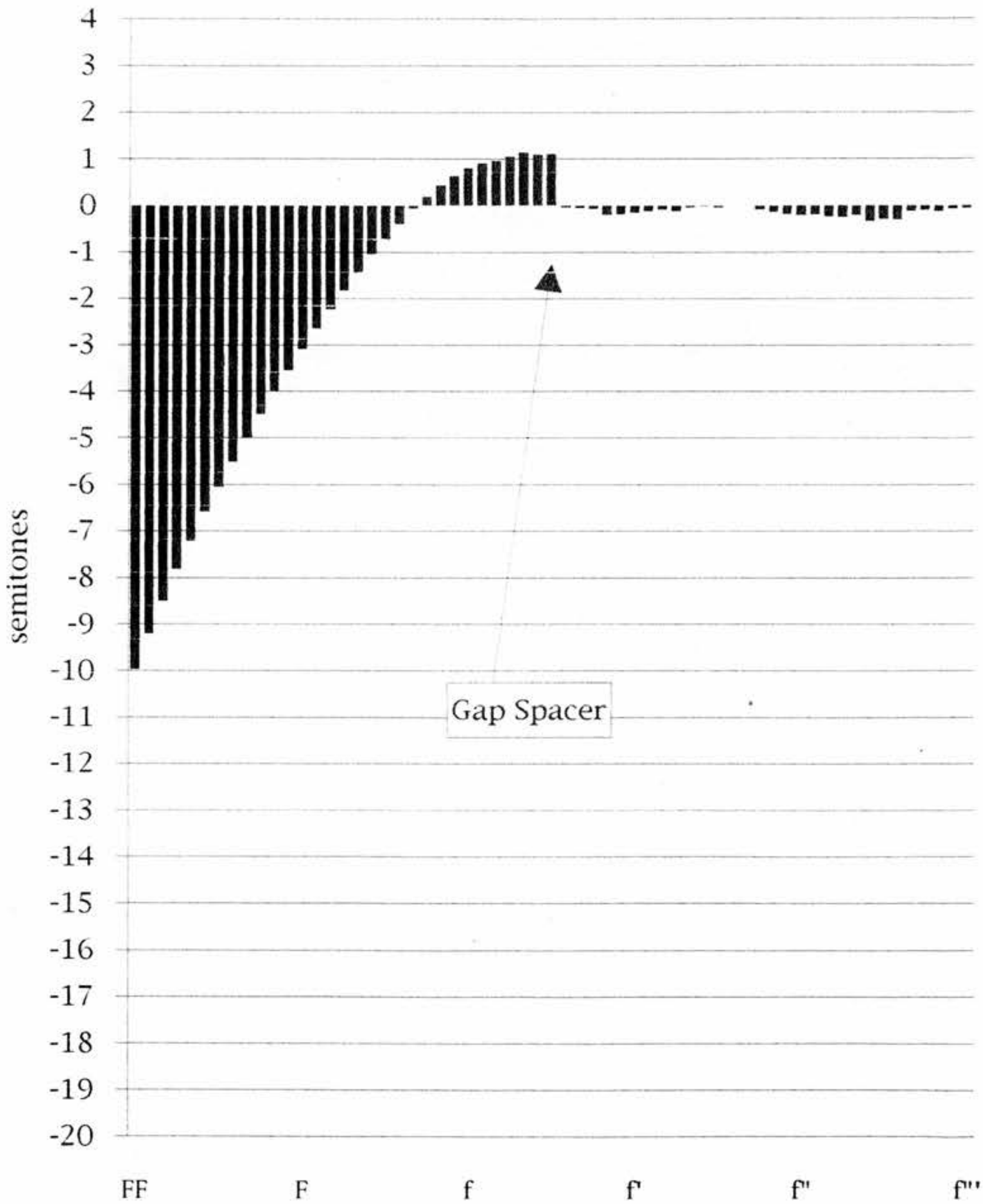


graph 27

The extra space taken up by the gap spacer in the string band varies from nothing, as for instance in those pianos with arching gap spacers, to the full width normally allotted to one choir of strings. In those pianos made by Stein between sometime in 1783 and 1790 there is a choir of dummy strings (known as the *Blindchor* in German) above the gap spacer making it look as if there is no interruption of the scaling. But in fact the string length of the note b, immediately to the left of the gap spacer, is a semitone too long (graph 26). The bridge, on the other hand, follows a curve based on a geometric progression with an 'octave' ratio of 1 : 1.95. In such cases it therefore appears that the curve of the bridge was the starting point for designing the scaling (graph 27). The lengths of the strings, including the dummy strings above the gap spacer, follow an 'octave' ratio of 1 : 1.95. Because the dummy strings are not used as sounding strings their presence incurs an interruption in the scaling pattern.

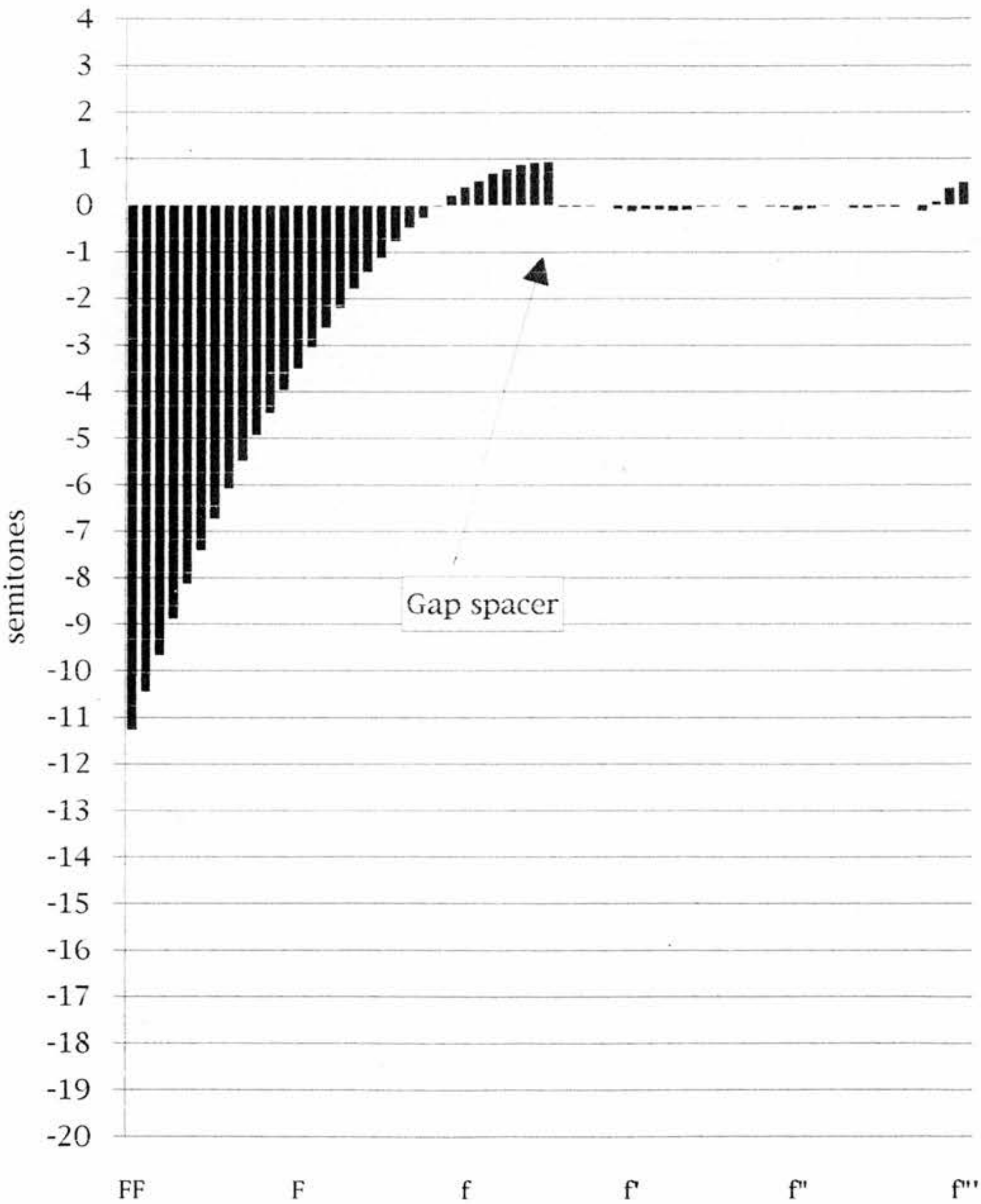
A number of Stein's followers, including Wirth, Lemme, Senft and Quante, also used a gap spacer. In their instruments, like in the later pianos by Stein, the curve of the bridge appears to have been taken as the starting point for the design of the scaling and no compensation for the discontinuity caused in the scaling by the gap spacer appears to have been made (graphs 28, 29, 30 and 31). From the few surviving instruments by these makers it appears that Wirth and Lemme used an octave ratio of 1 : 1.95, Senft used 1 : 2 and Quante used 1 : 1.92.

Grand Piano Franz Joseph Wirth c. 1790
{England}
Deviation of the string lengths from a curve
based on the length of c" and an octave ratio of
1 : 1.95 expressed in semitones



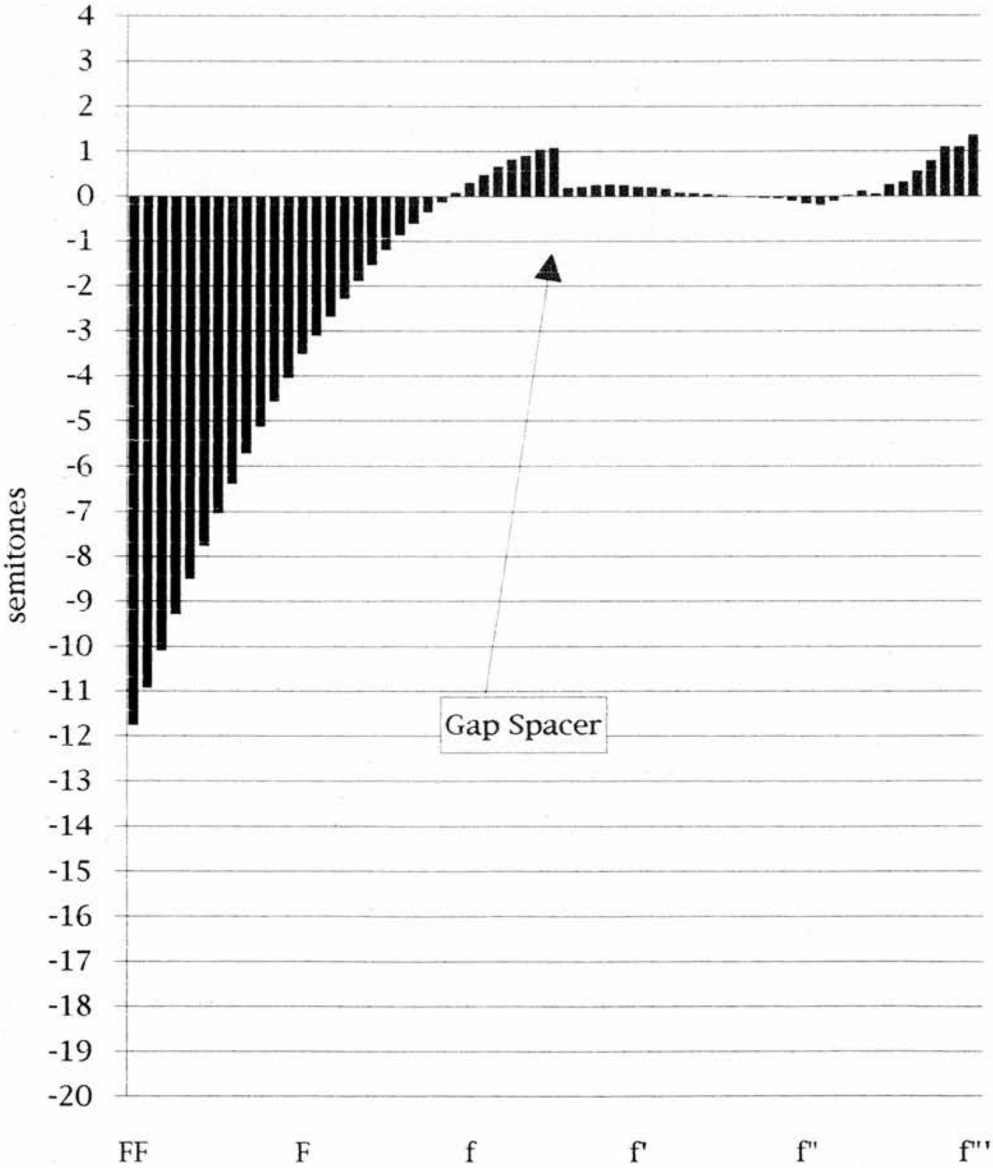
graph 28

Grand Piano Carl Lemme 1797 {New York}
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



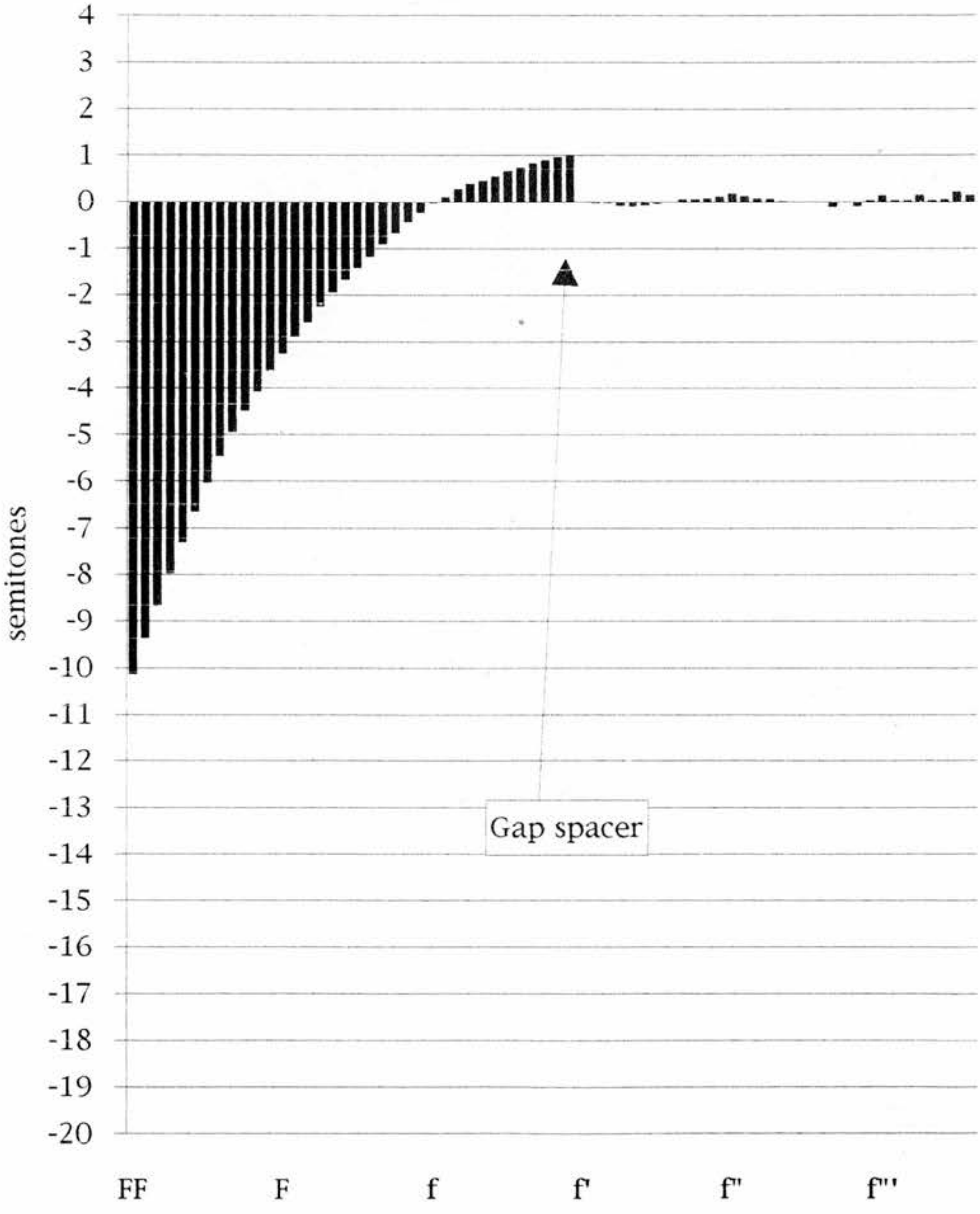
graph 29

Grand Piano Joseph Ignaz Senft c. 1795
{Nuremberg}
Deviations of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 30

Grand Piano Melchior Quante {Nuremberg}
Deviation of the string lengths from a
curve based on the length of c" and an octave
ratio of 1 : 1.92
expressed in semitones



graph 31

In a few pianos the gap spacer is accommodated by arranging the scaling such that the strings on the treble side are a half a semitone too short and on the bass side half a semitone too long. Hofmann's last surviving piano (H/c.1820) is one of these and others include a piano by Brodmann of 1818 and one by Schantz of about 1820 (see graphs 32, 33 and 34).

Brodmann and the gap spacer

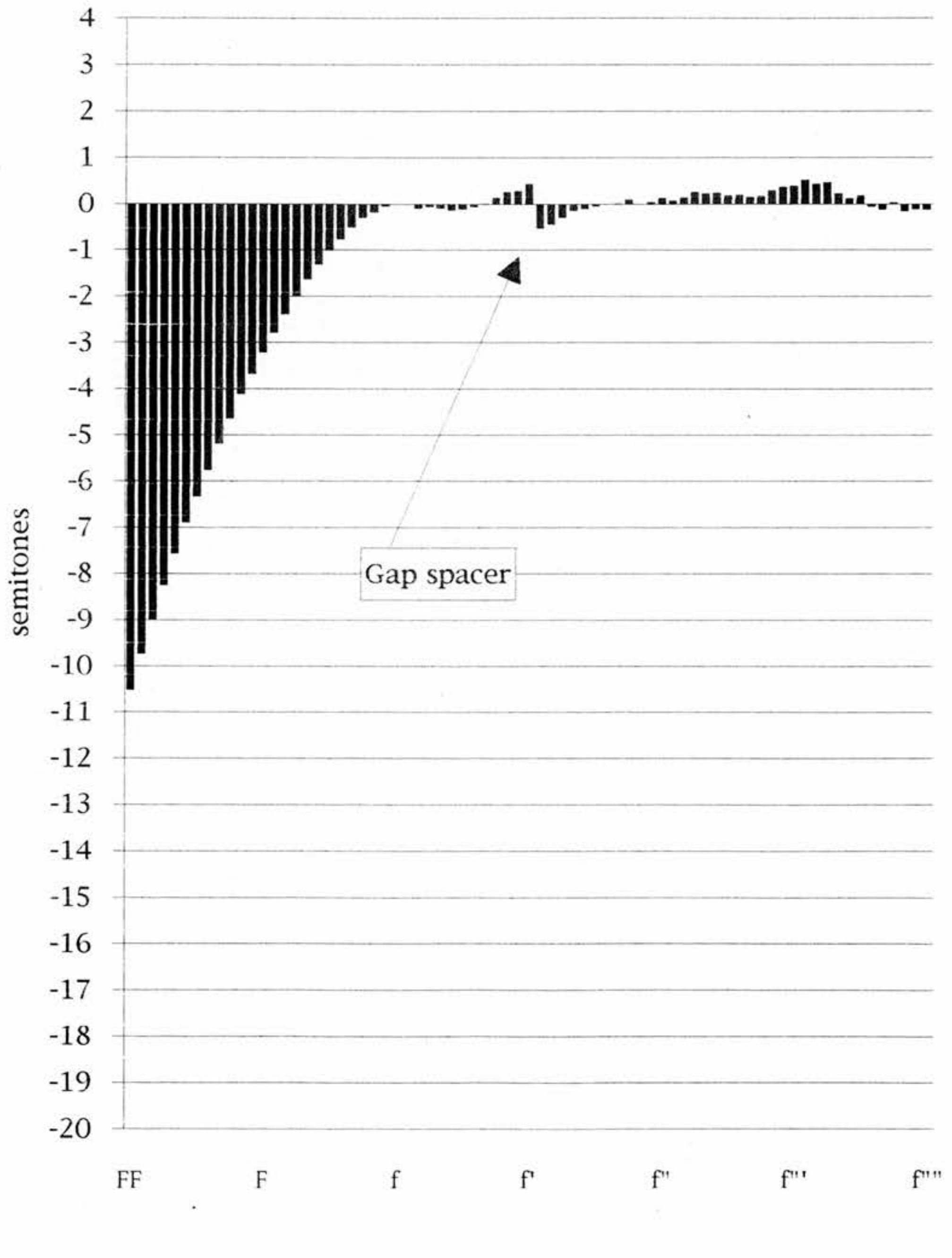
Brodmann appears to have been particularly concerned with reducing to a minimum the discontinuity in the scaling incurred by the gap spacer. Initially, around 1800, he allocated the gap spacer only 8mm of space in the string band, rather than the full width (13mm) occupied by a choir of strings, and thus reduced the total deviation from a geometric progression at the gap spacer from the normal semitone to less than half a semitone (graph 35).[203] In about 1805 he gave up using the gap spacer. When he resumed using the gap spacer in about 1818 he divided the discrepancy between the strings on either side (graph 33). Shortly before he sold his firm to Bösendorfer in 1828, Brodmann introduced the cranked bridge, that is, a bridge on which the line of the bridge pins makes a step at each gap spacer, presumably in order to

203 Of the two later pianos by Könnicke, K/7 (c. 1810), also has a minimum of space allotted to the gap spacer with a total discrepancy of less than half a semitone in the scaling progression (which follows an octave ratio of 1 : 1.95).

compensate for the discontinuity in the scaling (graph 36). The bridges of the pianos made by Streicher after about 1840 and those of the modern grand piano are cranked, ostensibly to compensate for the space occupied in the string band by the longitudinal cast-iron frame members.[204]

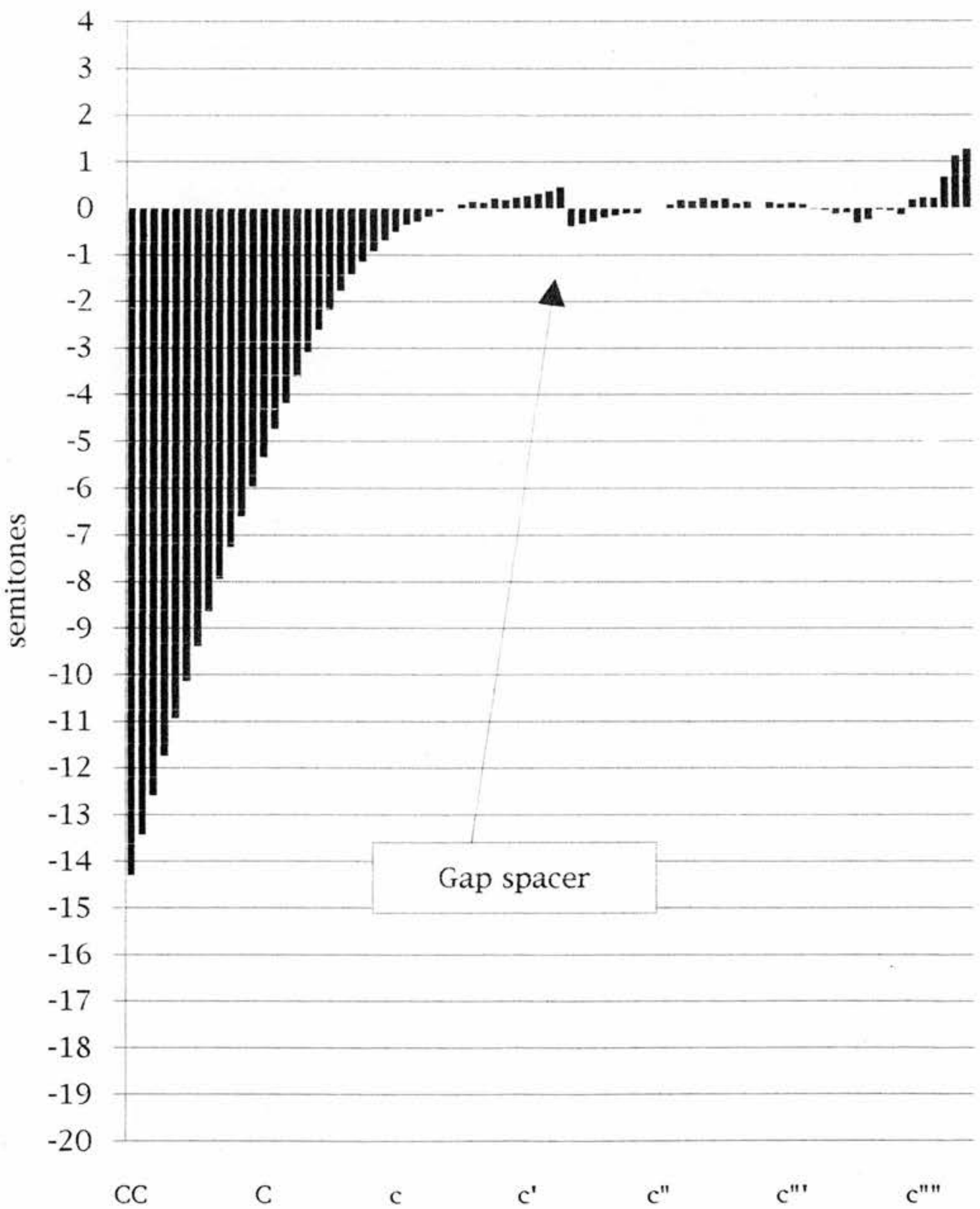
204 Although the cranked bridge had become standard by the 1840's pianos were still made late in the nineteenth century without a cranked bridge and hence large interuptions in the scaling caused by the longitudinal iron frame members. A grand piano by J. Schnabel of Vienna of 1885, AAA-a'''' with an iron frame has three bars in the treble without any form of compensation to adjust the scaling. Personal communication V. G. M. Wessels, November 1997.

Grand Piano Ferdinand Hofmann (H/c.1820)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



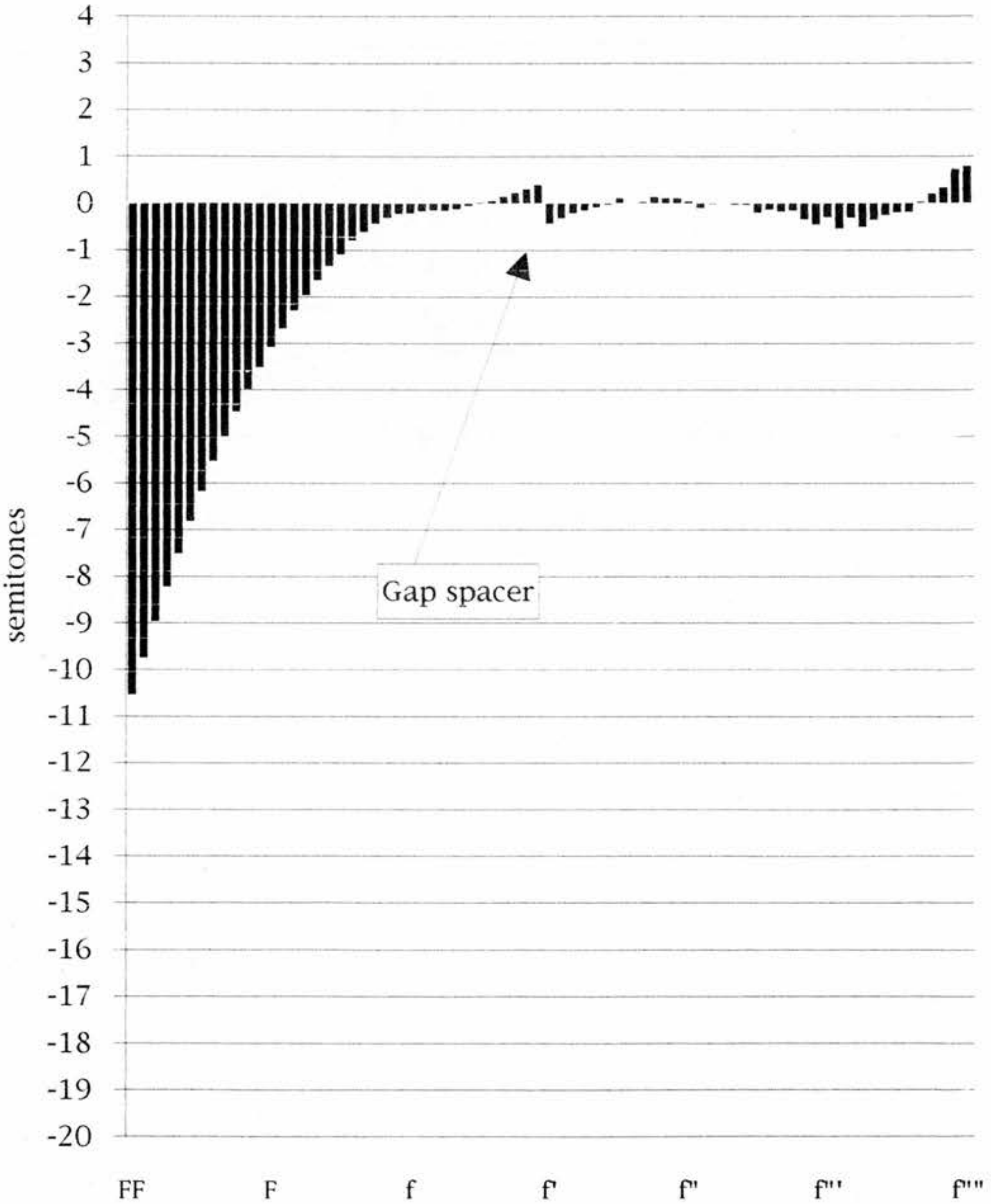
graph 32

Grand Piano Joseph Brodmann 1818 {Wörlitz}
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.97
expressed in semitones



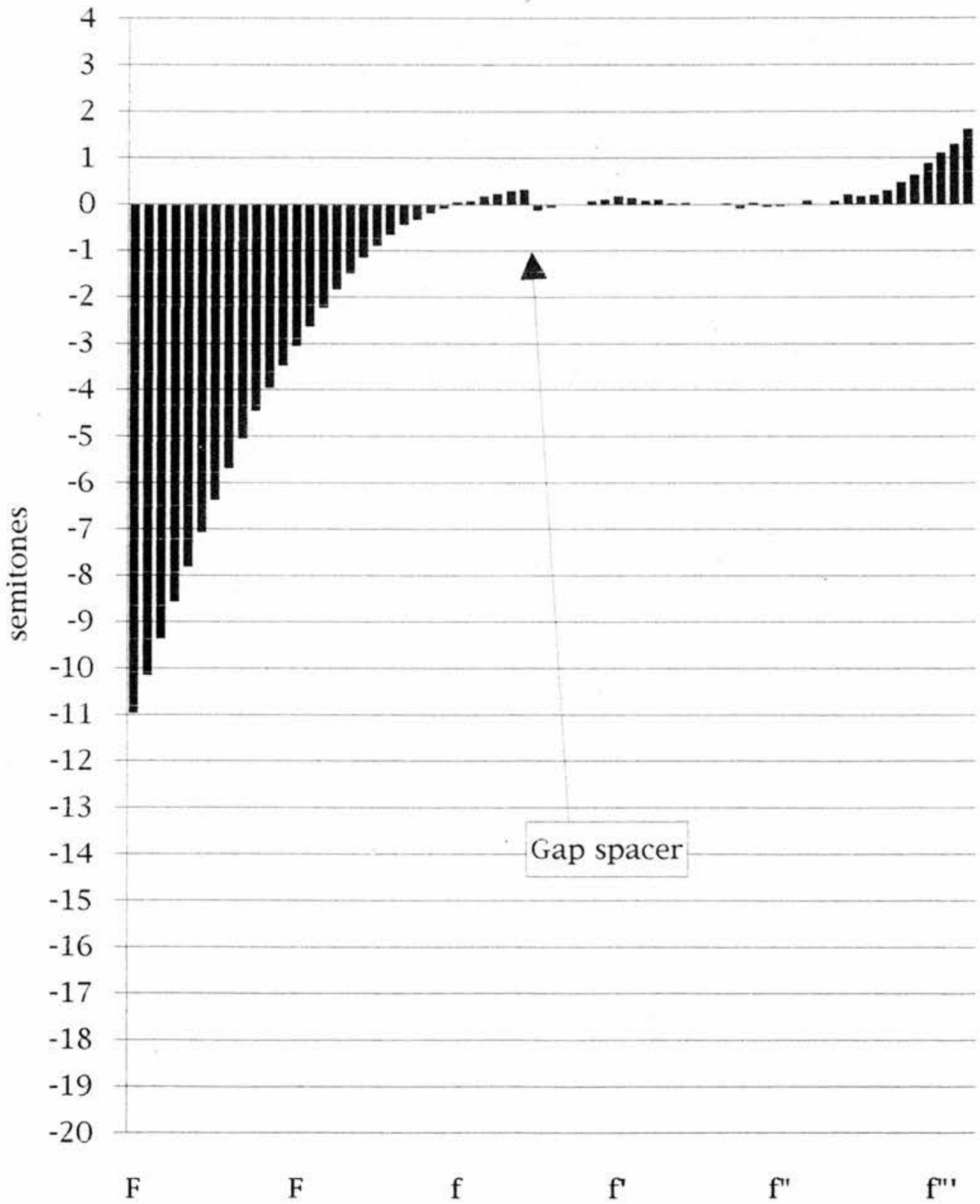
graph 33

Grand Piano Johann Schantz (Sz/18) c.1820
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



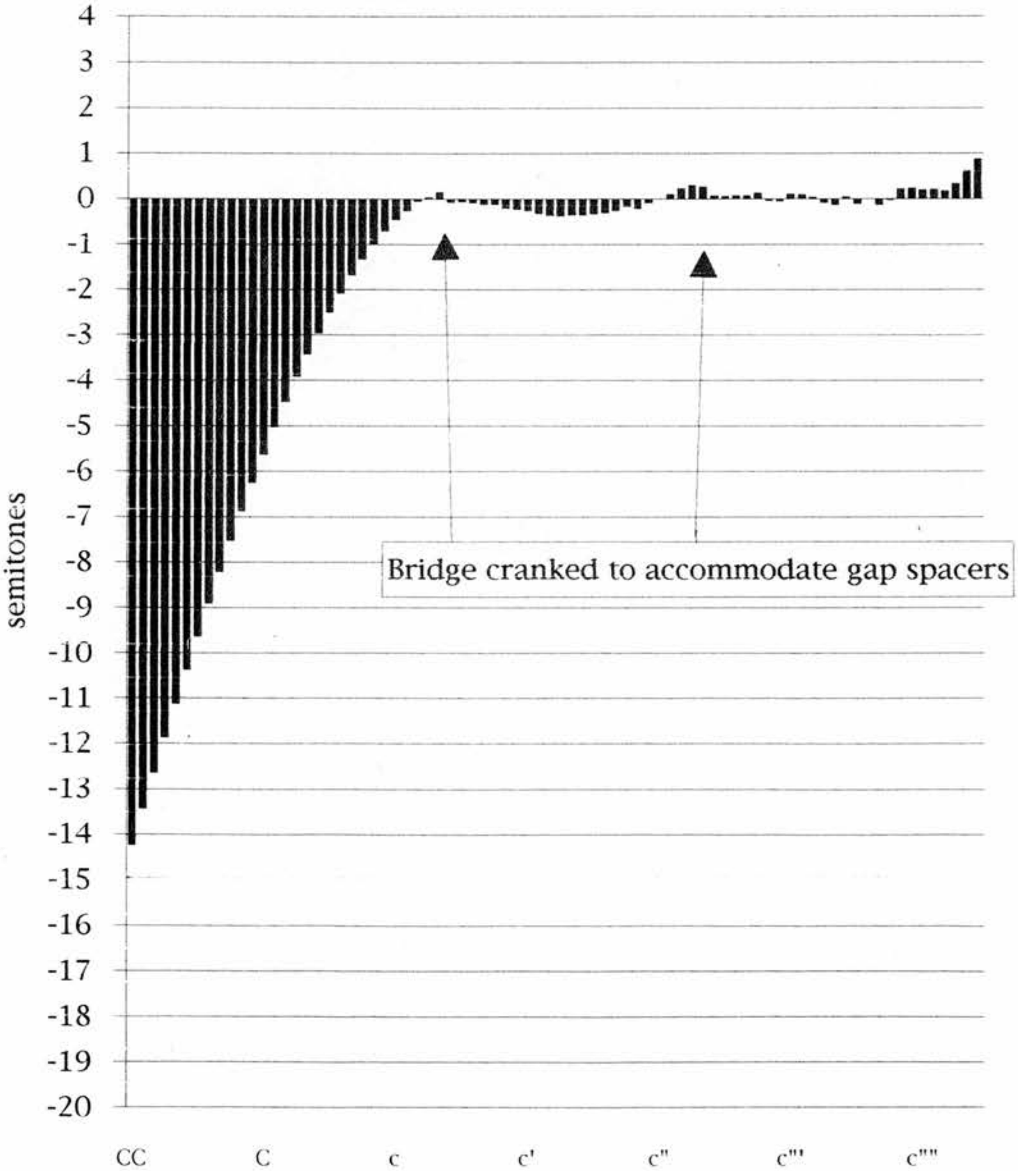
graph 34

Grand Piano Joseph Brodmann c.1800 {Halle}
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 35

Grand Piano Joseph Brodmann c.1825
{Netherlands 2}
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.97
expressed in semitones



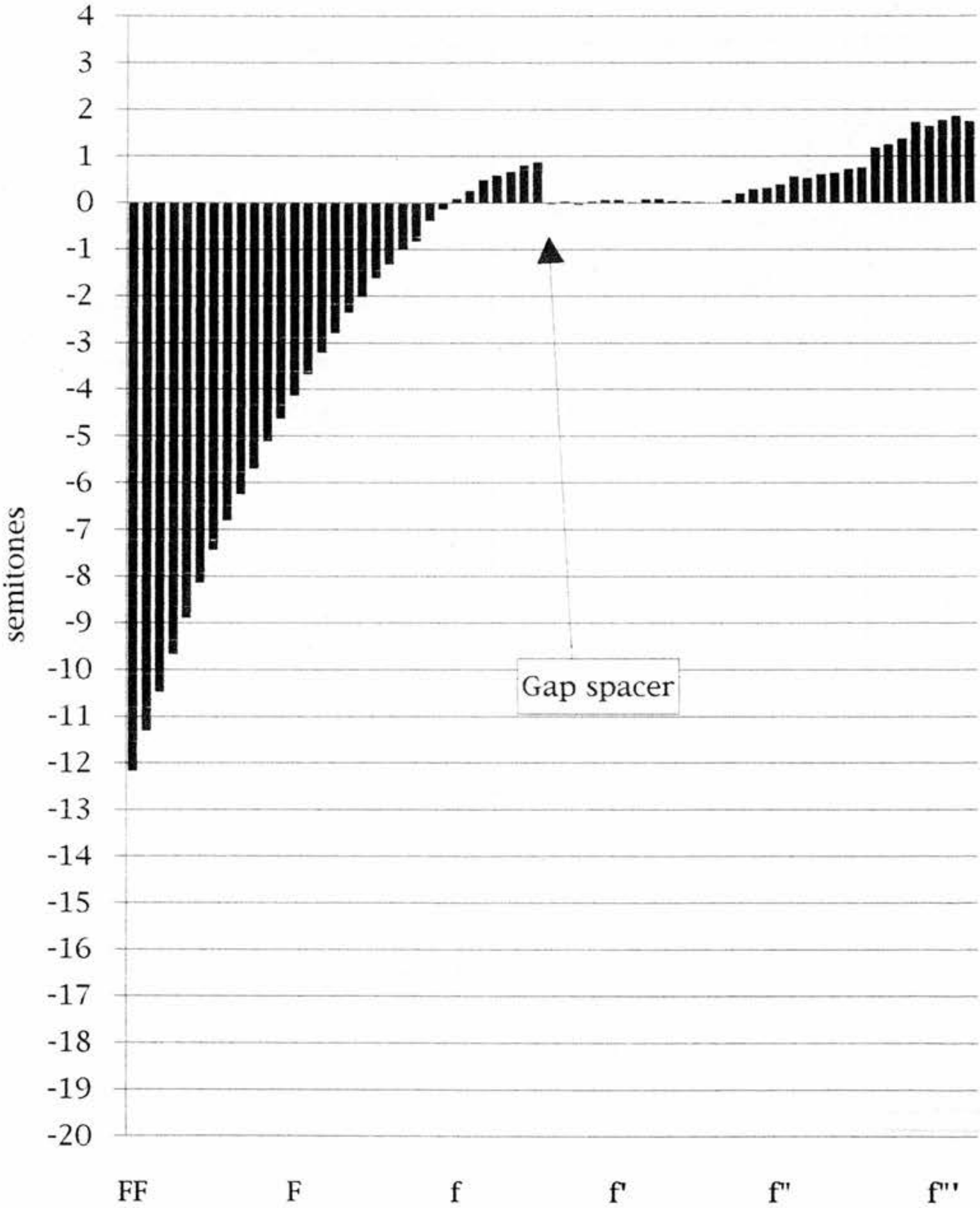
graph 36

Streicher and the gap spacer

After Stein's death his children continued to build pianos according to their father's general design. For instance, the pianos by the *Geschwister* Stein show the same treble stretching, varying between one and two semitones, as in Stein's pianos. The scaling at the single gap spacer, still placed between b and c', is arranged such that the strings for the note b are a semitone too long in relation to the those of c" as in Stein's later pianos (graph 37). But in one important respect Stein's children changed their father's design. The scaling of Stein's pianos, whether or not they have a gap spacer, follow an octave ratio of 1 : 1.95 whereas the pianos of his children follow Pythagorean scaling.

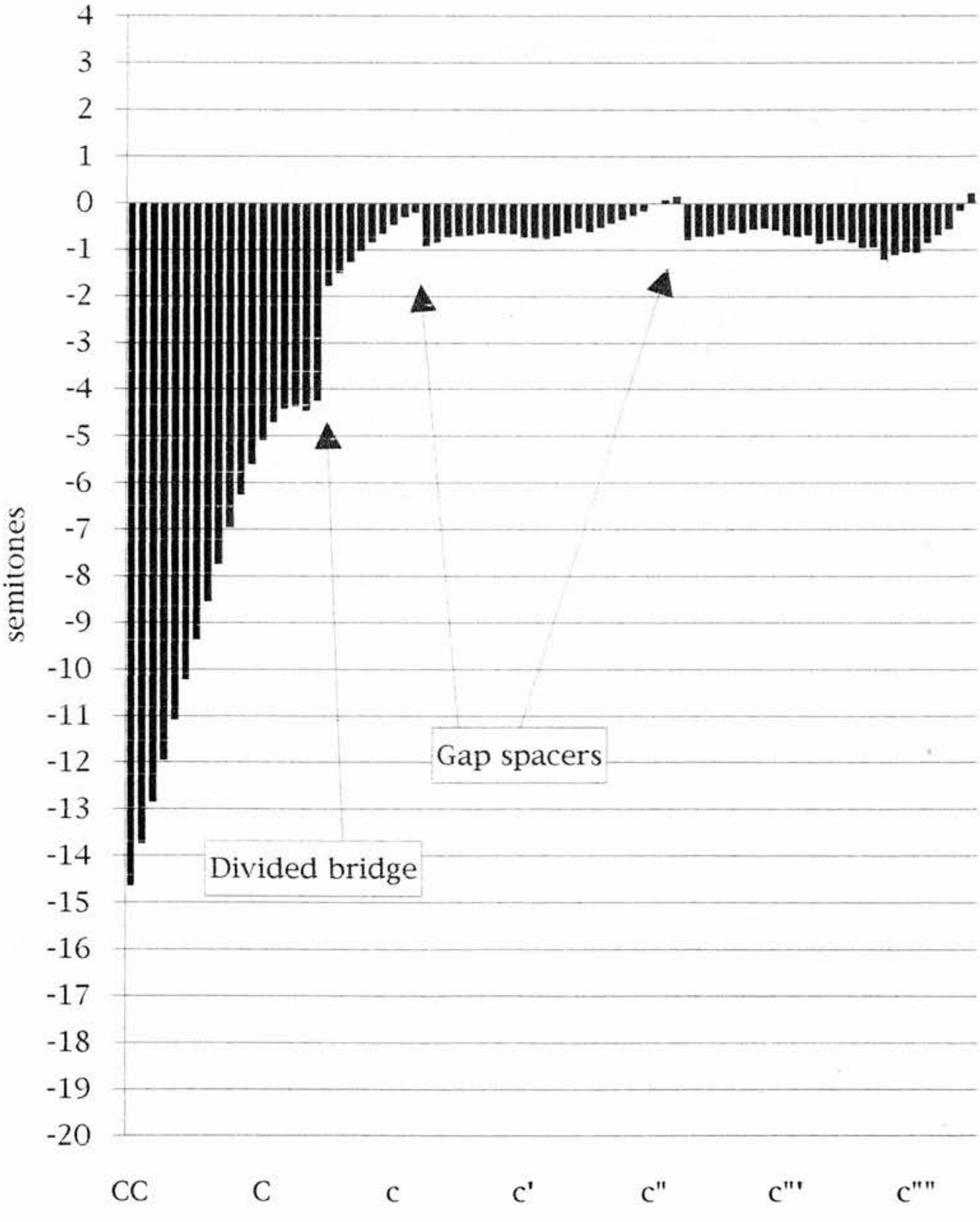
Nannette Streicher appears to have maintained the same scaling design until 1805. From 1805 (S/1805/673) to 1820 there are two gap spacers, placed between d and d# and between d" and d#" (graph 38). The strings on the right of each of these gap spacers, that is the strings for d# and d#", are a semitone too short while the strings to the left of the gap spacer have the correct lengths for a Pythagorean scaling based on the length of c". There is no appreciable treble stretching and almost all the notes from d#" upwards are about a semitone too short. All stretching of the scaling, both at the gap spacers and in the extreme treble, is thus avoided. The strings of the top note and of the notes on the bass side of both gap spacers conform to Pythagorean scaling and serve as three fixed points around which the lengths of the strings for the intervening notes appear to have been arranged.

Grand piano Geschwister Stein S/c.1796/27
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



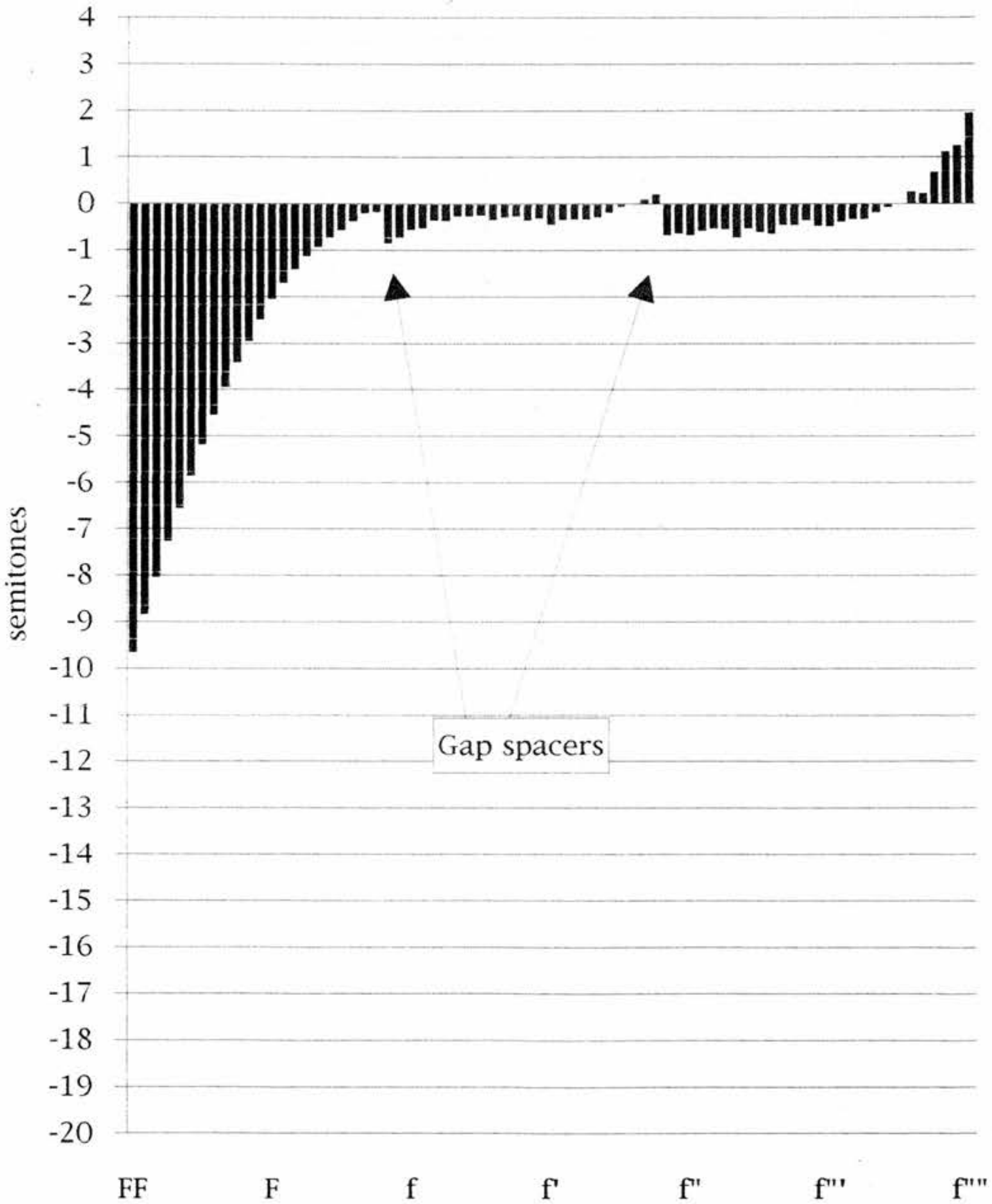
graph 37

Grand Piano Nannette Streicher S/1807/733
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



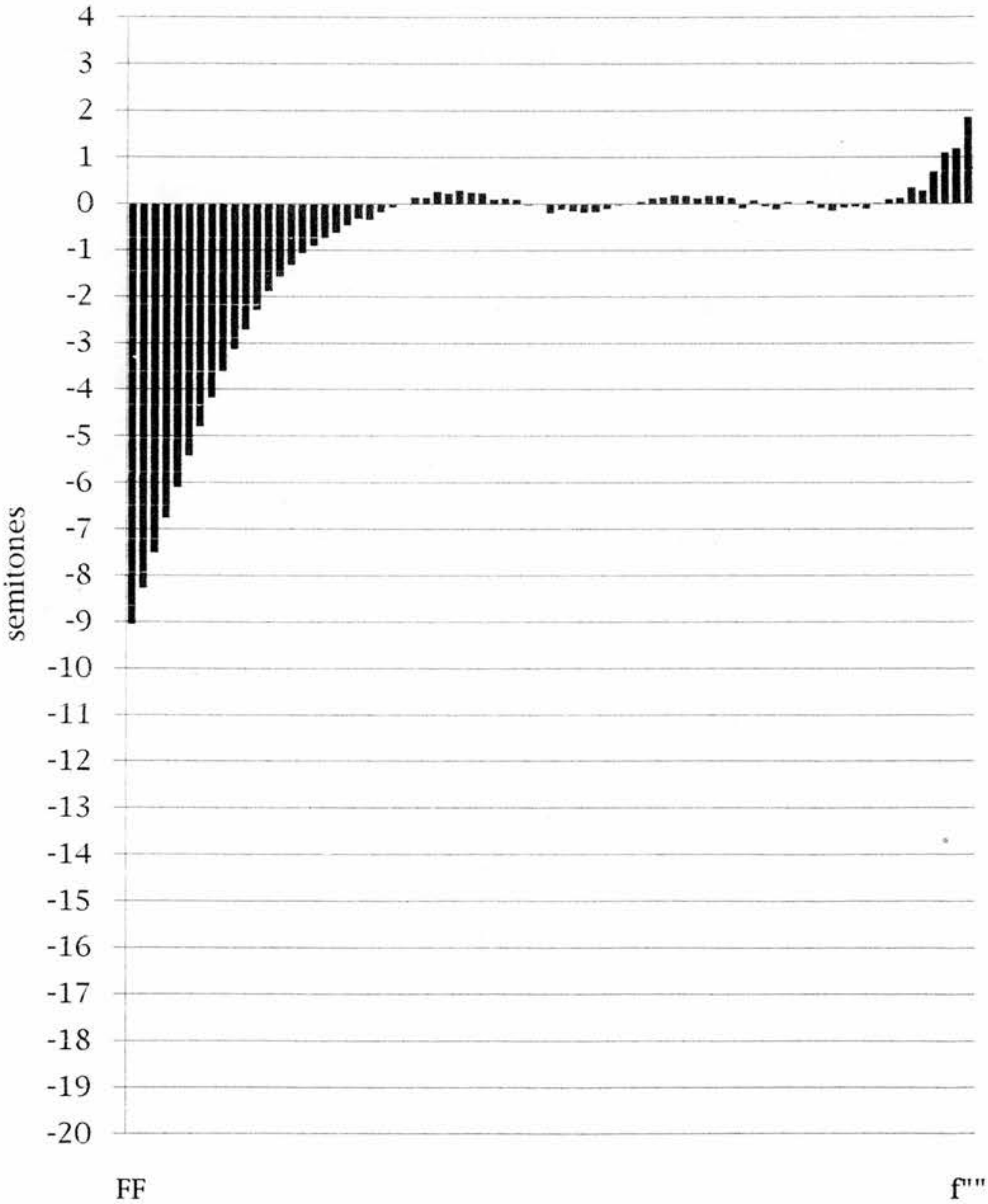
graph 38

Grand Piano Nannette Streicher S/1820/1550
Deviation of the curve of the bridge
from a Pythagorean curve based on the length
of c''
expressed in semitones



graph 39

Grand Piano Nannette Streicher S/1820/1550
Deviation of the curve of the bridge
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 40

The same scaling pattern is found in all the surviving pianos of Nannette Streicher from 1805 up to but excluding S/1820/1550.[205] The important change made in 1820 is the introduction of treble stretching, beginning at c'''' and reaching two semitones at f'''' (graph 39).

There is an alternative interpretation of the scalings of the pianos made between 1805 and 1820. The curve of the bridge (rather than the scaling) can be investigated by comparing the lengths of all the strings, including the dummy strings above the gap spacers, to the theoretical lengths generated by a geometric progression based on the string length of c''. The curve of the bridge is then found to follow a geometric progression based on the length of c'' and, seemingly, an 'octave' ratio of 1 : 1.95 (graph 40).

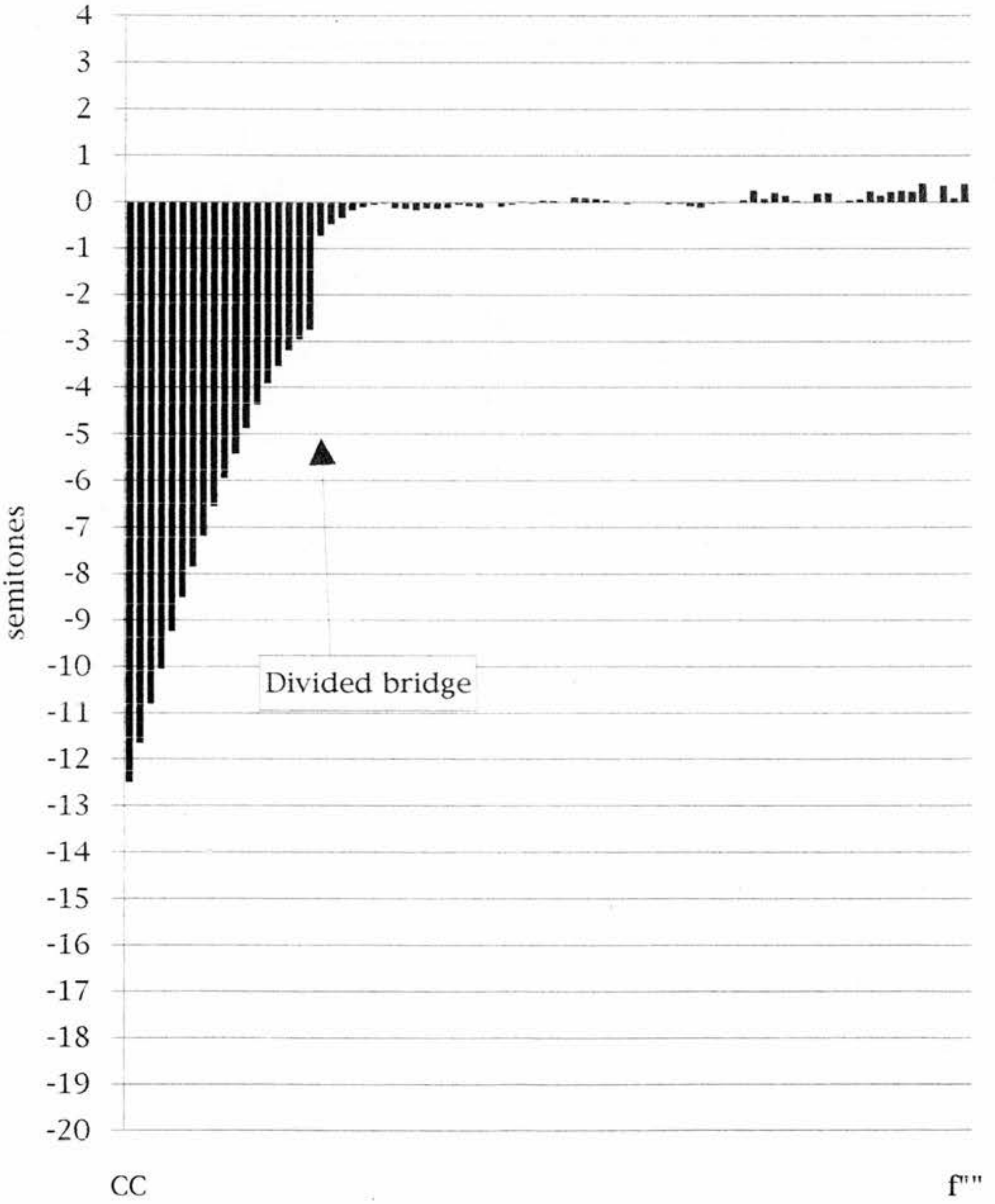
There are thus two interpretations of the scaling design used by Streicher between 1805 and 1820 indicating two possible starting points for designing the scalings of these pianos. Either a Pythagorean scaling could have been used as the starting point for the determination of the sounding string lengths or an 'octave' ratio of 1 : 1.95 could have been used as the starting point for the determination of the curve of the bridge. The scaling of S/1823/1756 is also susceptible to the same two interpretations (graphs 41 and 42). Either the scaling could have been designed according to the Pythagorean rule with the discrepancies at the gap

205 S/1811/902 is an exception in that there is treble stetching and the note d, immediately on the bass side of the gap spacer is also stretched. But the bridge on this piano is loose and the instrument is in such condition that the string lengths cannot be deemed reliable. S/1816/1117 and S/1816/1147 both have new soundboards. Their string lengths are thus also unreliable.

spacers (now at a/a# and a"/a# ") equally divided either side or the curve of the bridge could have been designed according to an 'octave' ratio of 1 : 1.95.

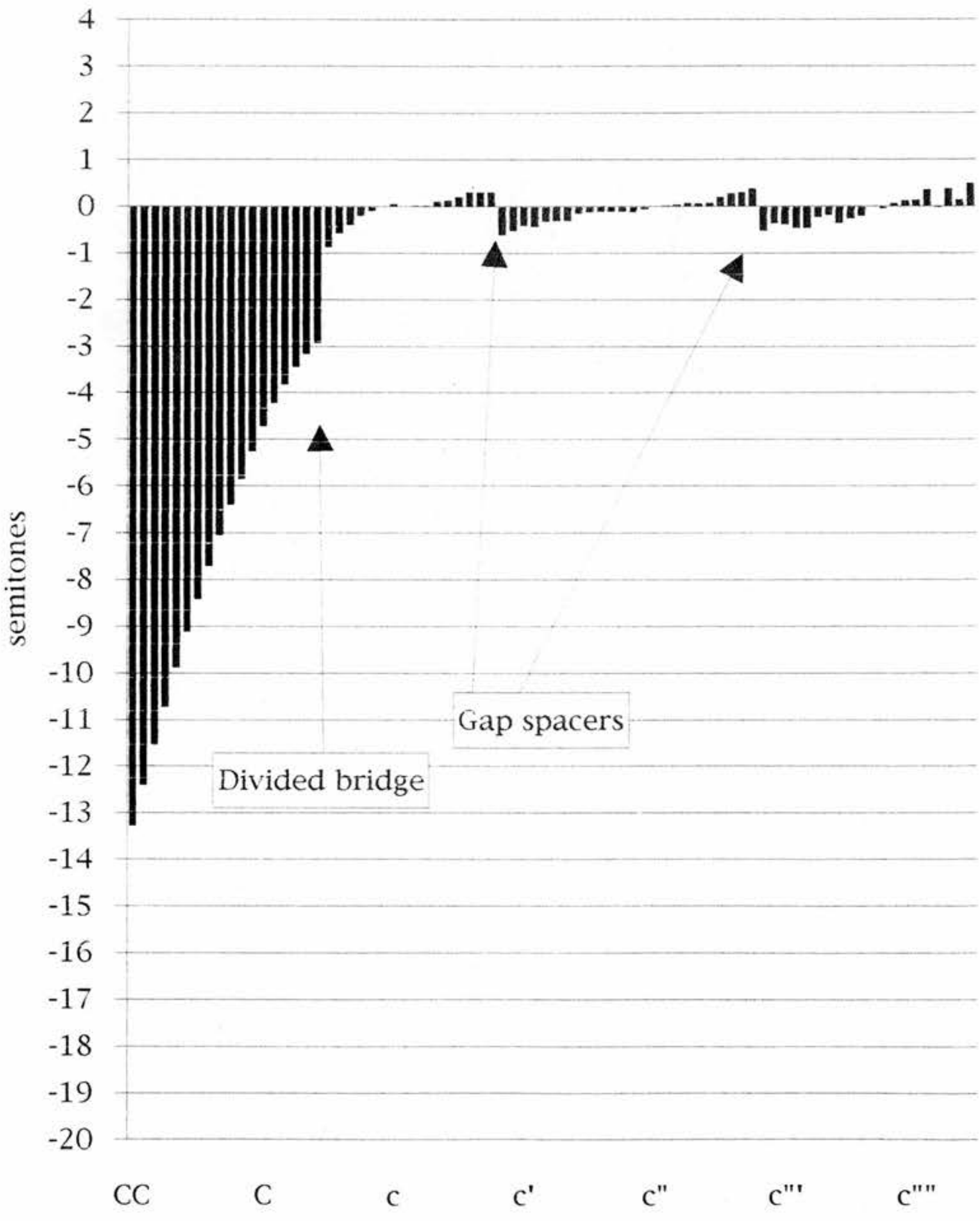
It could be conjectured that both interpretations are correct, that Streicher knew that by designing the curve of the bridge according to an 'octave' ratio of 1 : 1.95 the result would be a set of string lengths which conform to an octave ratio of 1 : 2 after interpolating the two gap spacers and their dummy strings. But it seems to be more by chance than design that the apparent use of an 'octave' ratio of 1 : 1.95 for the curve of the bridge results in a Pythagorean scaling. In these instruments there are 25 choirs of strings for each two octaves, for instance from c' to b" inclusive. The extra choir is the set of dummy strings above the treble gap spacer, either between d" and d# " or between a" and a# ". Streicher probably determined the string lengths by using 24 Pythagorean semitones for 25 choirs of strings, one of which was the dummy choir. There is thus little doubt that the apparent use of the ratio 1 : 1.95 for the curve of the bridge in Streicher's instruments is fortuitous and rests on the fact that the use of 24 Pythagorean semitones for 25 choirs of strings is very close to the true use of the ratio 1 : 1.95 in which 23 Pythagorean semitones are used for 24 choirs of strings.

Grand Piano Nannette Streicher S/1823/1756
Deviation of the curve of the bridge
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 41

Grand Piano Nannette Streicher S/1823/1756
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones

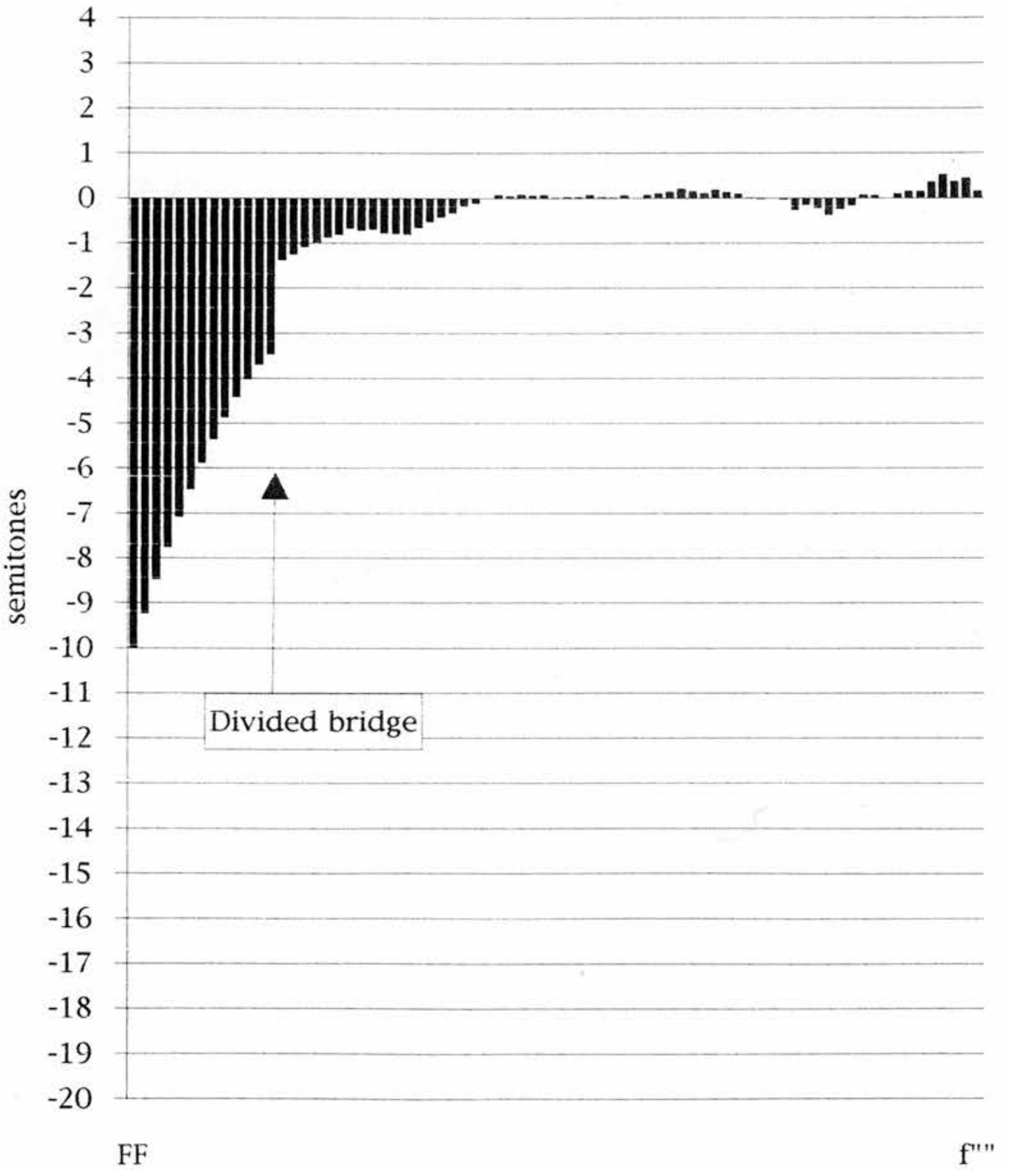


graph 42

Except for the down-striking instruments, the pianos by the Streicher firm of after 1823 and until at least 1830 show the same scaling pattern as S/1823/1756, although neither the curve of the bridge nor the scaling approximate a geometric progression as closely as in the piano of 1823. The string lengths roughly follow a Pythagorean scaling and the curve of the bridge appears to more or less follows a geometric progression with an 'octave' ratio of 1 : 1.95, for instance in S/1828/2237 (graphs 43 and 44).

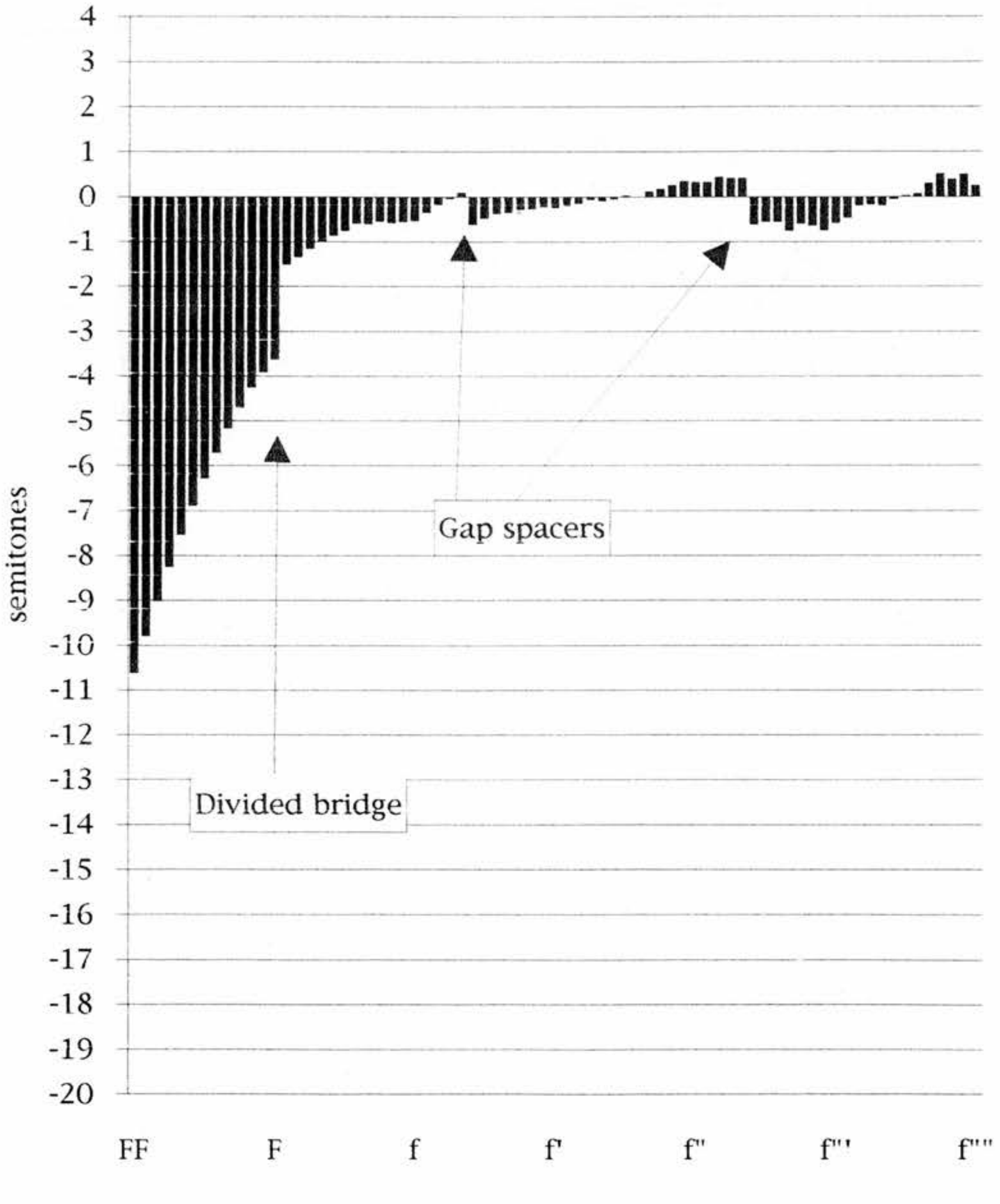
Evidence that the Pythagorean principle was still the Streichers' starting point for designing their scalings, however, is provided by the down-striking pianos. These instruments have no gap spacers and their string lengths closely approximate a Pythagorean scaling (graph 45) supporting the idea that the starting point for the Streichers' design was an octave ratio of 1 : 2 and that the apparent use of an 'octave' ratio for designing the curve of the bridge is indeed a matter of coincidence.

Grand Piano Nannette Streicher und Sohn
S/1828/2237
Deviation of the curve of the bridge
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



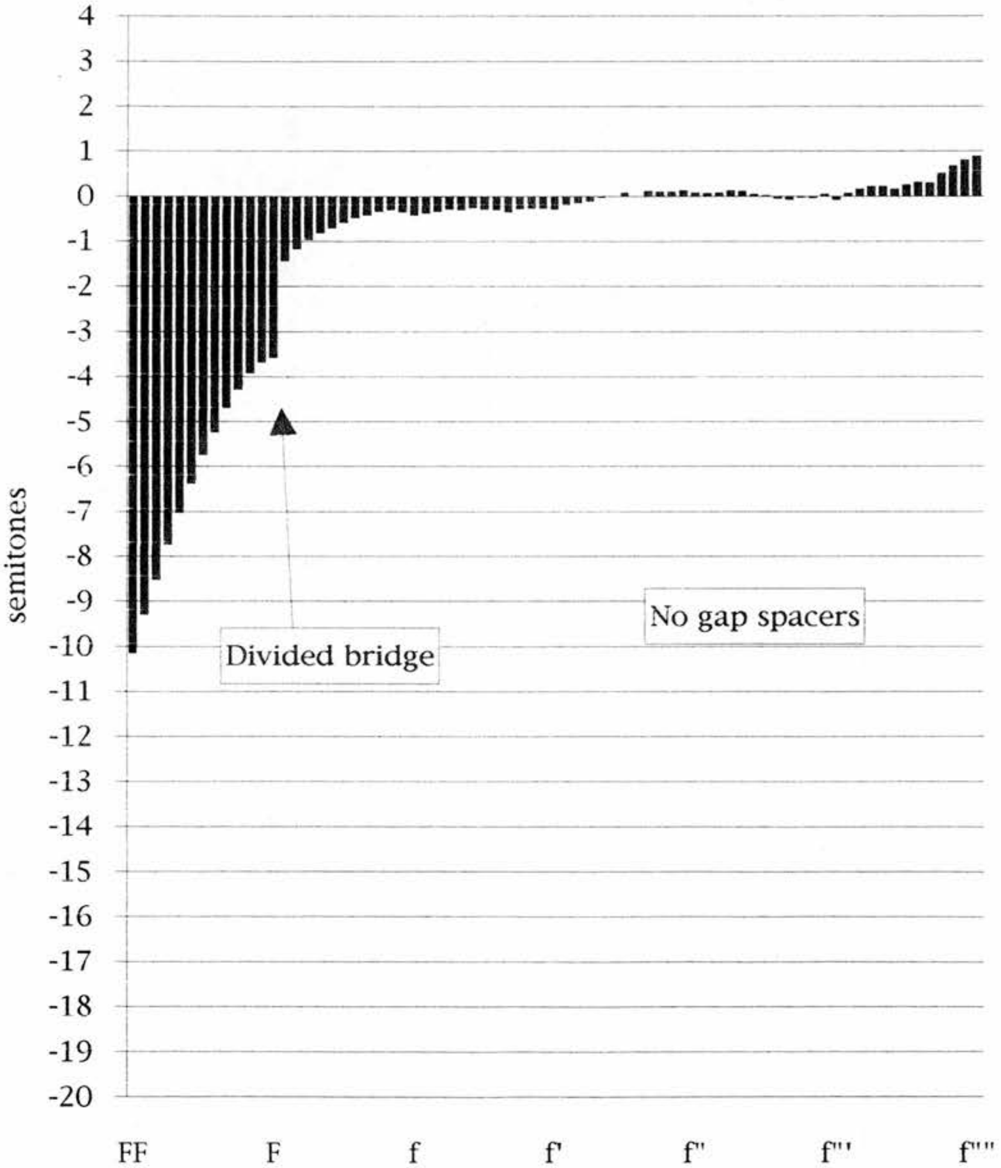
graph 43

Grand Piano Nannette Streicher und Sohn
S/1828/2237
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 44

Grand Piano (down-striking) Nannette Streicher
und Sohn S/1826/2053
Deviation of the string lengths
from a Pythagorean scale based on the length of
c"
expressed in semitones



graph 45

Walter and the gap spacer

All the pianos by Walter of before about 1810 are designed with wider action parts for all the d notes, including their damper blocks, key levers and escapement hoppers. The key levers for each note d are about 2mm wider than all the others, the escapement hoppers for each note d have 2mm extra space allotted to them and so on. At first one might suppose that this would have entailed considerable extra work. But it is more likely that a simple method of marking out and sawing the keyboard is the reason behind the principle of the wide d.

As in Italian harpsichords, the tails of the d keys in the traditional layout of the visible part of the keyboard in Viennese pianos are wider than the tails of the other naturals. Most Viennese builders used such wide d key tails but marked out and cut the key levers such that all of them, including those of the d's, were of equal widths at the back of the action. The sides of the key levers of the d's converged towards the back. In contrast, Walter simply sawed out the d key levers with straight parallel sides such that at the back of the action the key tails are as wide as at the front, that is, 2mm wider than all the other key tails. This means that all the action parts, including the hammers, also require 2mm extra space. This facet of Walter's design is referred to here as the extended wide d principle.

The bridge pins and nut pins were almost certainly marked out according to their distances perpendicular to the spine. To accommodate the more widely spaced d hammers, both the nut pins and bridge pins for all the d's were also allotted an extra 2mm measured from the spine. This leads to a very slight discrepancy in the scaling at each d. If, for instance, the d' string has a length of 490mm and conforms to a Pythagorean scaling, $c^{\#}$' will be about 4mm too long, a discrepancy of less than 0.2 of a semitone (less than 1% in length).[206] Graph 46 shows the small irregularities in the scaling curve around the d's. There is no consistency in the irregularities, either within individual instruments or from one instrument to the next; sometimes the $c^{\#}$ string is slightly too long, sometimes the d string is too short and sometimes it is the $d^{\#}$ string which is too short.

The early instruments by Walter have no gap spacer.[207] From about 1790 until 1805 there is a single gap spacer placed between $c^{\#}$' and d' in the pianos with the range FF to g'''. By choosing this position advantage is taken of the wider separation between the bridge pins and nut pins of the $c^{\#}$' and d' strings. In the pianos with the range FF to f''' the gap spacer is placed between b and c'.[208] In the latter instruments the nut pins (but not the bridge pins) for the notes b and c' are moved to the side in order to make extra room for the gap spacer. This in turn makes the distances between the nut pins for $a^{\#}$ and b and between $c^{\#}$' and d' narrower than usual. There are thus untidy and inconsistent

206 The discrepancy in the length of $c^{\#}$' is comparable to the difference in the lengths of the two strings of the choir for the note d'.

207 W/c.1782a, b, c, d & e, and W/c.1785a, b & c.

208 Why Walter did not place the gap spacer between $c^{\#}$' and d' in these pianos is a mystery.

irregularities in the nut pinning either side of the gap spacer. One has the impression that a solution to the nut pinning around the gap spacer was improvised as each instrument was pinned. The result, nevertheless, is that there is no appreciable discrepancy in the scaling due to the gap spacer (graph 47).

The extended wide d principle was used in all three surviving grand pianos by Pfister, a maker who settled in Würzburg and who had been a journeyman in Walter's workshop. These pianos by Pfister date from about the first five years of the nineteenth century. They have three gap spacers, unusual for that time, each of which occupies only 2mm of extra space in the string band. Catholnick, probably a follower of Walter, also used the principle of the extended wide d in his three surviving grand pianos and placed the gap spacer between c#' and d', again such that the discrepancy in the scaling negligible. Johann Grünenthal, another Viennese builder, and Ludwig Gress of Graz both used the extended wide d principle and placed the gap spacer between c#' and d'. There is, however, only one surviving grand piano by Gress and one by Grünenthal. Gröber used the extended wide d principle in at least two of his pianos. He placed the gap spacer between d' and d#'.[209]

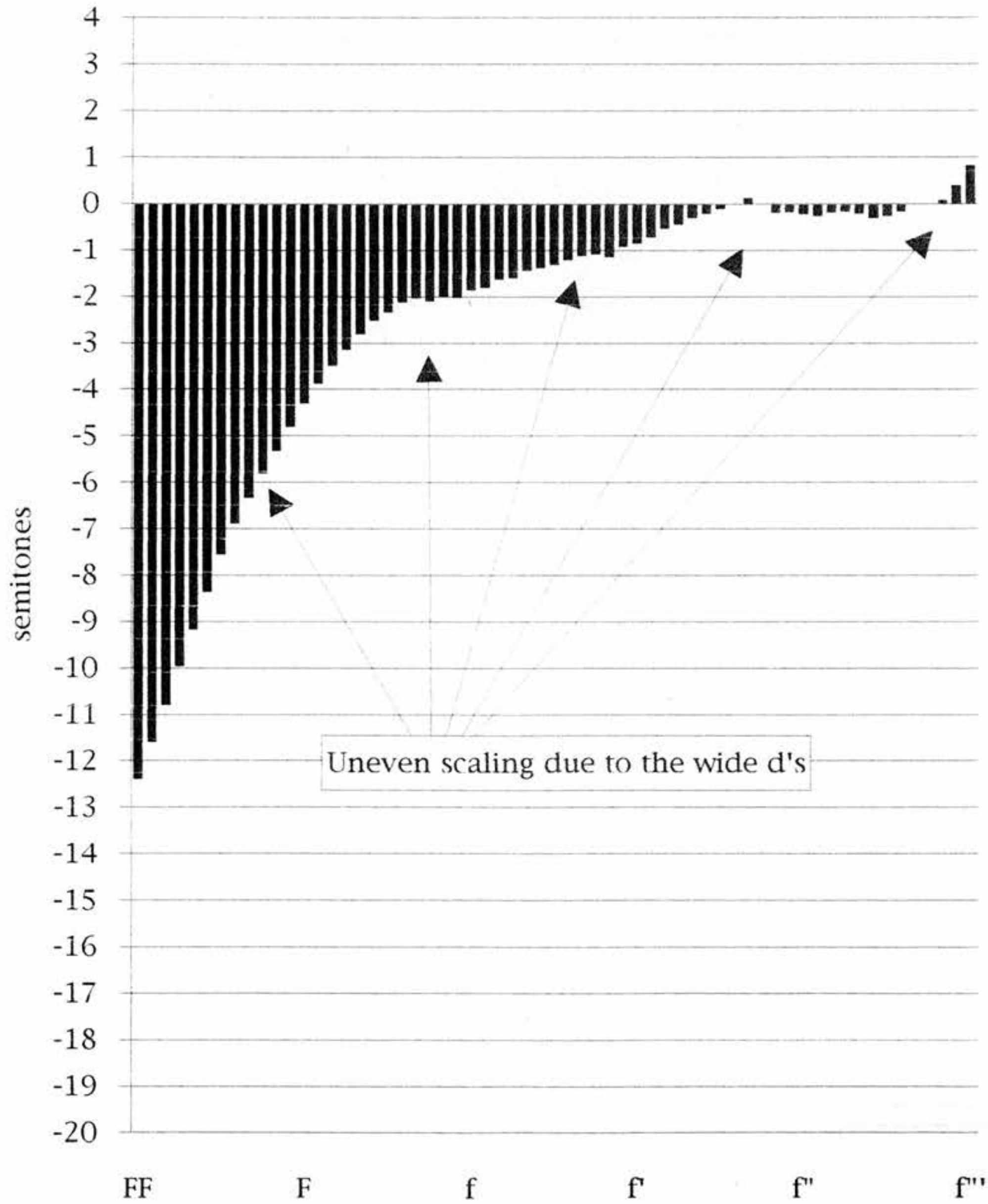
The extended wide d principle may be used as an indication that a particular builder was apprenticed to Walter although not all

209 The pianos by Catholnick are {Halle}, {England} and {U.S.A.}. The instruments of Catholnick, Pfister, Grünenthal and Gress all have the same means of adjusting the escapement as in the pianos by Walter. The two pianos by Gröber are {England} and {New Haven}.

his followers used the extended wide d. Both Rosenberger and Fritz, considered here as followers of Walter, allocated no extra space to the action parts and strings of the d's. The oldest surviving piano by Fritz (F/1) has two gap spacers, one placed between c#' and d', as in the pianos of Walter, and the other between g" and g#". All other pianos by Fritz have only one gap spacer. In F/2, F/3 and F/3a it is placed between b' and c". In such instances in which the gap spacer is placed next to c" it is clear that that another note must be used as reference when analysing the scaling.[210] The scaling of F/3a is shown in graph 48 using c" as reference and in graph 49 using f" to illustrate this point.

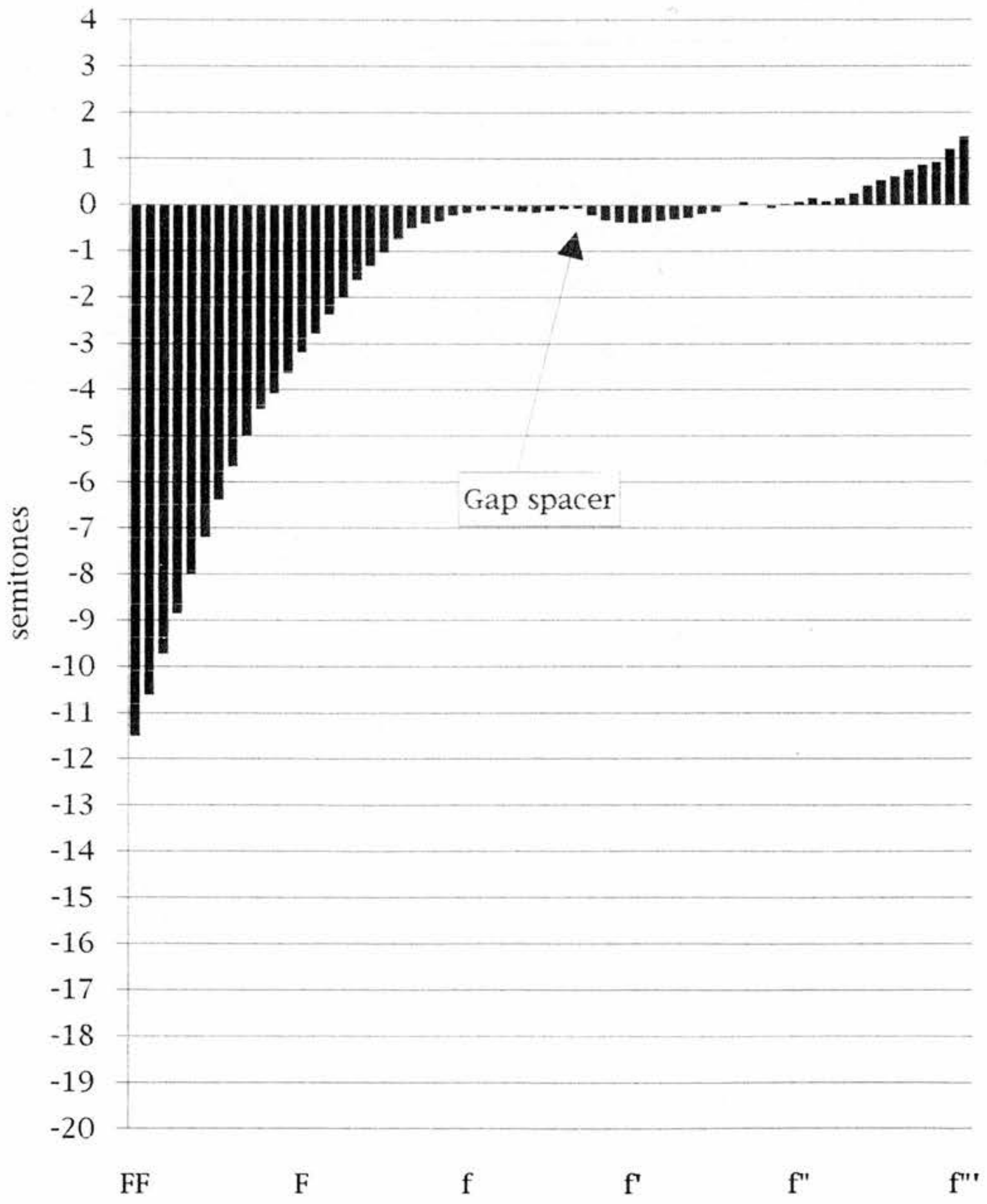
210 This emphasises that the use of c" is arbitrary and only valid if c" falls within that part of the compass which has string lengths which follow a geometric progresssion.

Grand piano Anton Walter W/c.1782a
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



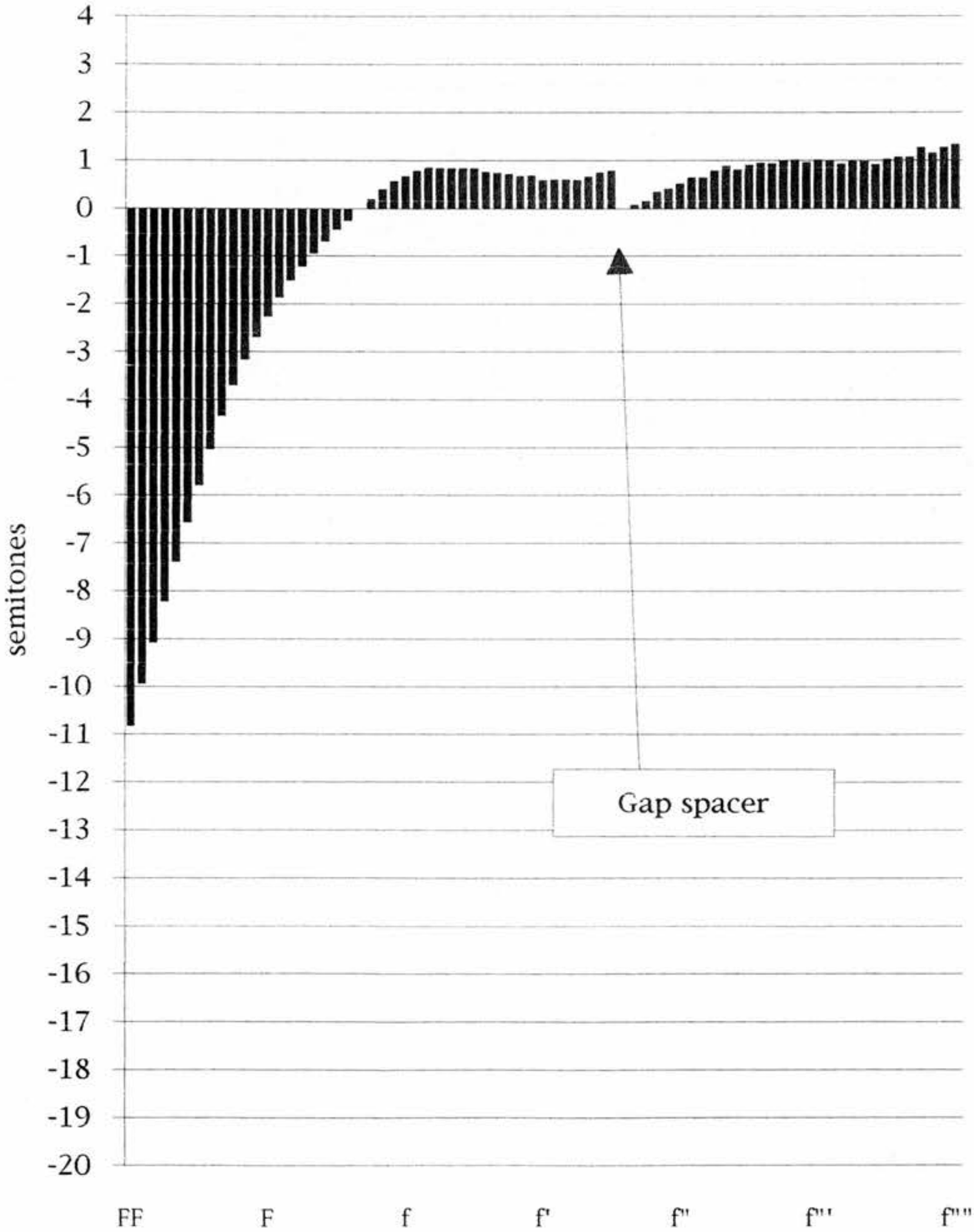
graph 46

Grand piano Anton Walter W/c.1800a
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



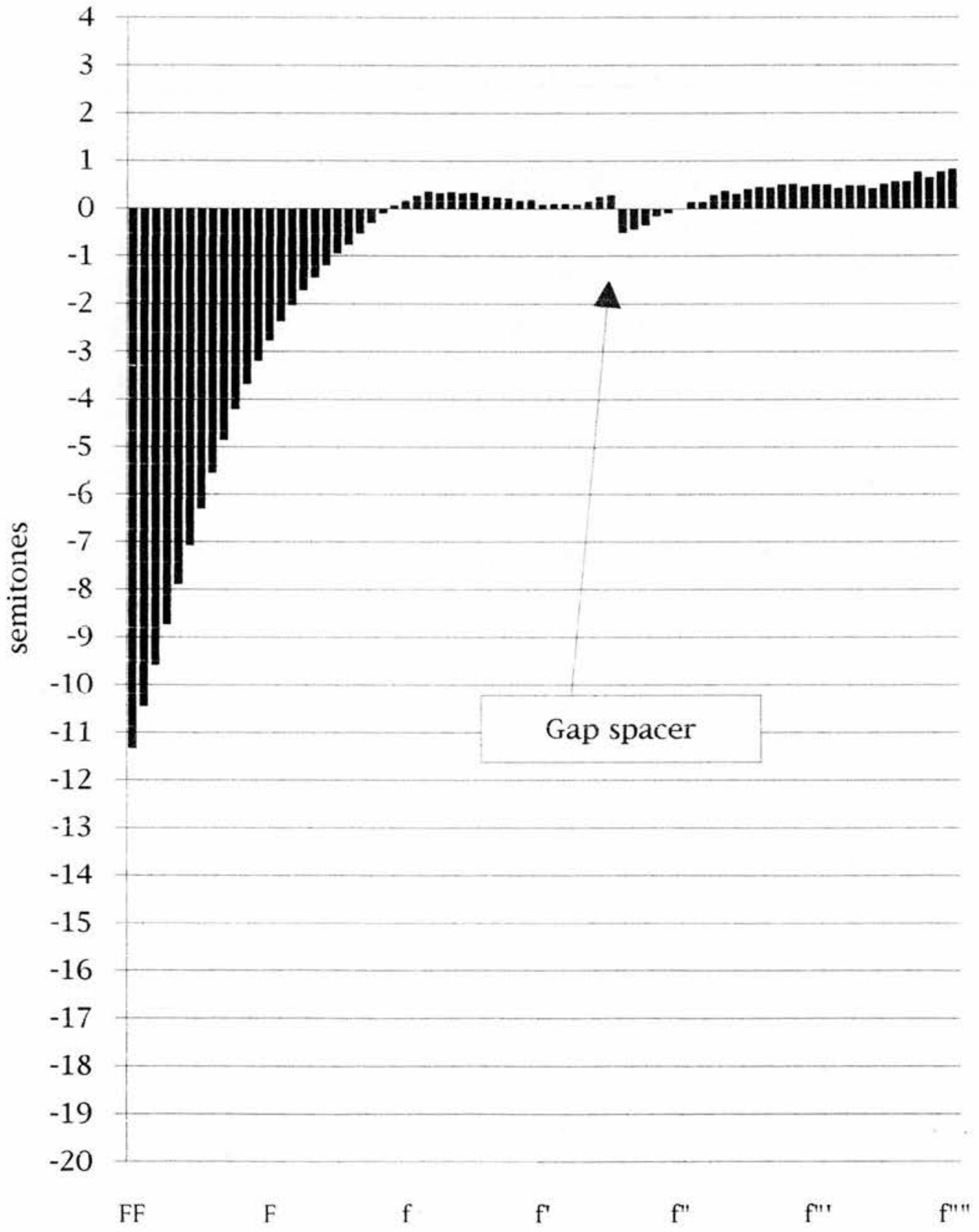
graph 47

Grand Piano Johann Fritz c.1815 (F/3a)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



graph 48

Grand Piano Johann Fritz c.1815 (F/3a)
Deviation of the string lengths from a
Pythagorean scale based on the length of f''
expressed in semitones



graph 49

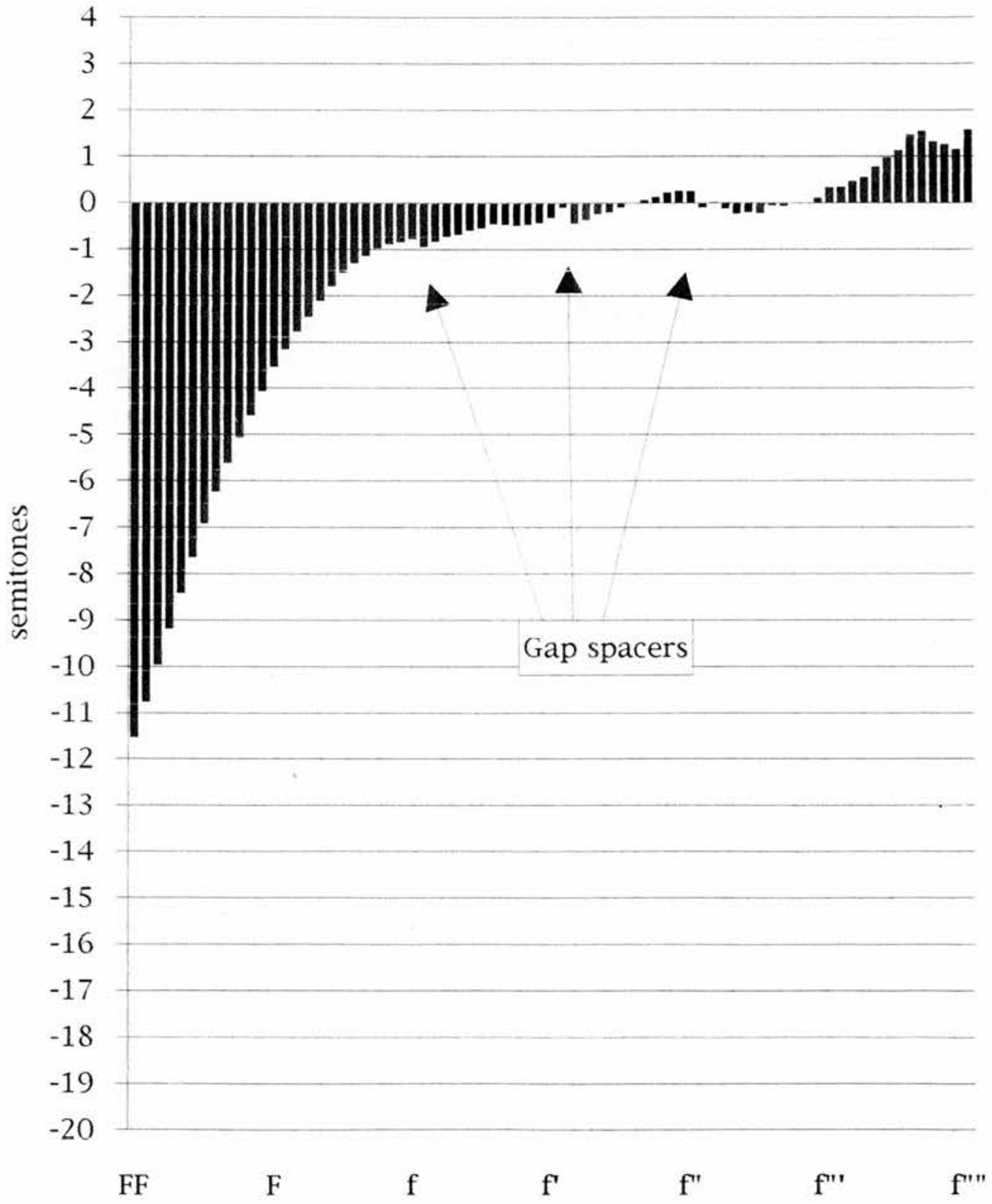
Walter did not continue to use the wide d principle in his six-octave pianos. In these instruments, made in about 1815, there are three gap spacers (instead of one) each of which is placed between two choirs of strings spaced about an extra 5 mm further apart, both at the nut and at the bridge, giving slight discontinuities in the scaling (graph 50). In the earlier instruments, squeezing the gap spacer between two hammers left no room to shift the action for a *una corda* stop. The six-octave instruments have the extra space for the gap spacer and all of them are provided with a *una corda* stop.

In a six-octave piano made between about 1815 and 1820 Walter returned to the single gap spacer, placing it between f' and f#'.[211] The scaling is interrupted by a little less than a semitone. Finally, in the piano of about 1820 there are two gap spacers, between the notes a and a# and between the notes f" and f#", each interrupting the scaling by a semitone (graph 51).

Many of the pianos by the Walter firm have string lengths which do not accurately follow a geometric progression. On the other hand, except in the 1820 piano, every effort appears to have been made to prevent the presence of the gap spacer from interrupting the smooth progression of the string lengths from long to short.

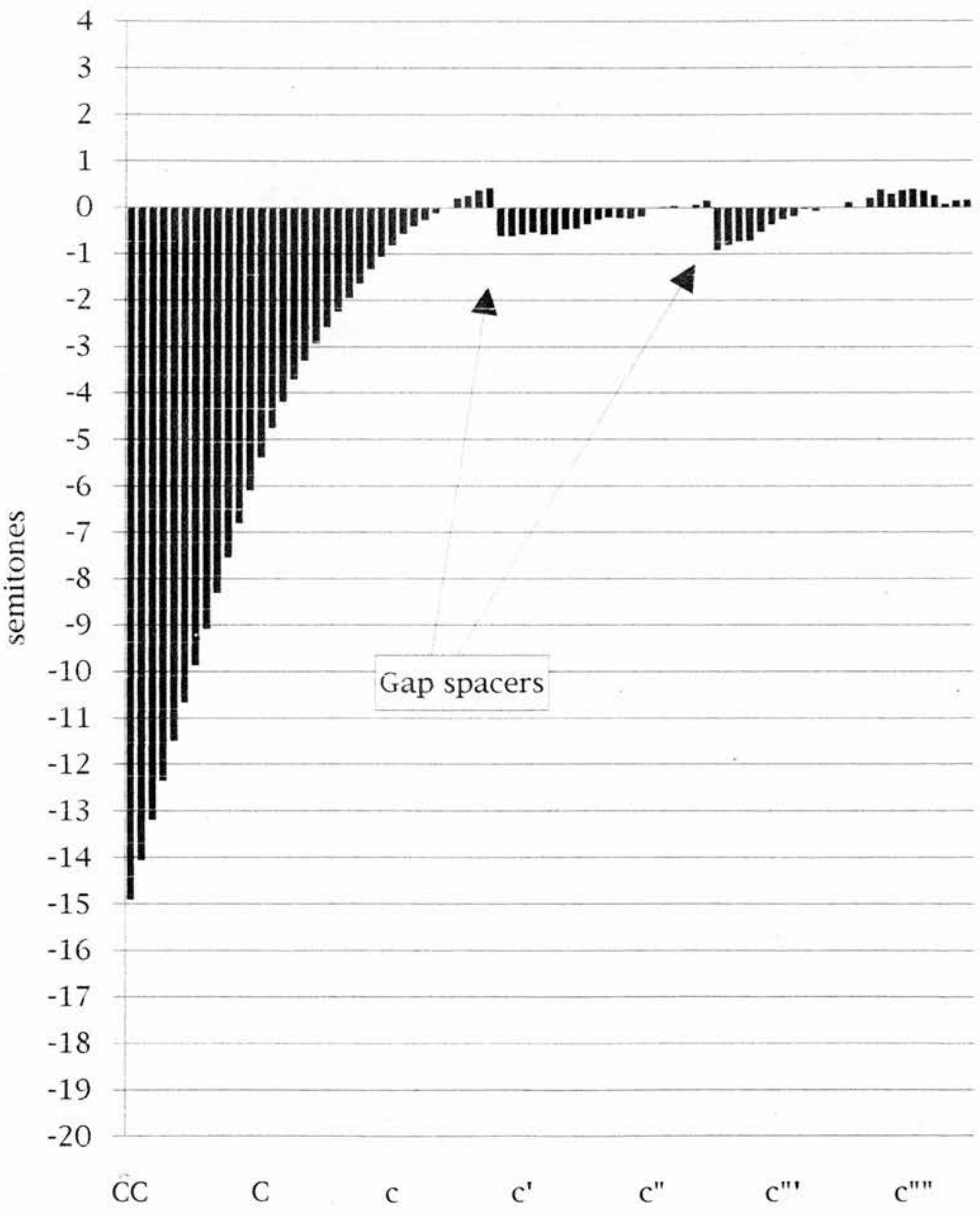
211 W/c.1817.

Grand piano Anton Walter und Sohn W/c.1815e
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 50

Grand piano Anton Walter und Sohn W/c.1820
Deviation of the string lengths
from a Pythagorean scale based on the length of
c"
expressed in semitones



graph 51

Scaling and the gap spacer: summary and conclusion

The different ways, summarised in the following list, in which the various makers accounted for the gap spacer in their scaling designs may shed some light on their attitudes to the effects of scaling on sound.

1) Hofmann, Stein and Stein's followers usually allocated the gap spacer about 13mm in the string band, the width normally occupied by a choir of strings, such that the string lengths immediately on the bass side of the gap spacer were a semitone too long.

2) From 1805 until about 1820 Nannette Streicher allocated each of the gap spacers the width occupied by a choir of strings but such that the strings on the treble side of each gap spacer were a semitone too short.

3) In some pianos by other makers, including most of those by Fritz, some late pianos by Schantz and the last piano by Hofmann, the discrepancy of a semitone in the scaling is divided between the strings of the notes either side of the gap spacer.

4) In their pianos with gap spacers Brodmann and Könnicke reduced the width allotted to the gap spacer from the usual 13mm to about 8mm, thus reducing the discrepancy in the scaling to less than half a semitone. This discrepancy they then divided between the notes either side of the gap spacer. In those of his earlier pianos with a gap spacer Schantz also reduced the width allotted to the gap spacer and reduced the total discrepancy in the scaling to a little more than half a semitone.

5) Walter and some of his followers reduced the extra width allotted to the gap spacer to about 4mm, reducing the discrepancy in the scaling to a negligible amount. In his later instruments with three gap spacers and a *una corda* stop Walter appears to have continued to try to keep the intrusion of the gap spacers to a minimum.

6) At least two makers, Brodmann and Schantz, gave up the gap spacer for short periods during the first two decades of the nineteenth century, long after the use of gap spacers had become normal.

Whether or not they were concerned with the idea that the string lengths should follow a geometric progression, Walter, Brodmann, Könnicke and, to a lesser degree, Schantz appear to have been reluctant to allow the gap spacer to cause an interruption in the smooth progression of the scaling.

Other makers, including Stein, Streicher and Hofmann appear to have made no attempt to adjust the scalings of their pianos to compensate for the interruption in the scaling caused by allotting the gap spacer the space normally occupied by a choir of strings. If these makers had been concerned with the accuracy of their scalings, for instance as a means of ensuring a particular sound spectrum for their pianos, they could easily have positioned the gap spacer so that the discontinuity was minimalised, as did Walter and, to a lesser extent, Brodmann, Könnicke and Schantz.

There thus appear to have been at least two different attitudes to scaling. On the one hand there were makers who seem to have tried to maintain the smooth progression of the string lengths from long to short and, on the other hand, makers who seem to have thought nothing of creating a hiatus in the scaling pattern by interpolating a gap spacer. These two approaches may reflect two different opinions regarding the effect of the scaling on the sound. Those who reduced the discontinuity caused by the gap spacer could have believed that an even tone was dependant on a smooth scaling. Those who tolerated the hiatus in the scaling probably relied on good voicing to deal with any unevenness in the tone caused by the scaling discontinuity, just as one would have had to smooth over the unevenness in the tone at the changeover from brass to iron or from one string gauge to another. In this respect it is interesting to note that Walter appears to have tolerated the small discrepancies in the scaling caused by his extended wide d principle but not the larger discrepancy caused by allotting the gap spacer the width occupied by a choir of strings.

Case length, bass foreshortening and treble stretching

Bass foreshortening is likely to be related to case length.[212] These two variables are now discussed in relation to different makers. At the same time the extent and variation in treble stretching is described.

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212 All case lengths given here exclude mouldings and other protrusions.

The pianos of Stein and Streicher: case length, bass foreshortening and treble stretching

The data relating to the scaling and case lengths of the pianos of the Stein and Streicher firm is summarised in table 55. The lengths of FF and c" for S/1783f are given as 'n/o', 'not original'. This instrument has a new soundboard and the scaling has been radically altered. In other pianos either a new soundboard, a new wrestplank or other major repairs make the string lengths untrustworthy. Such instances are indicated by the use of italics. Where no data is given this indicates that the necessary measurements have not been taken. The large letter C after an instrument code indicates a range starting with CC rather than with the normal FF of the other instruments.

The pianos of Stein, excepting those in the three combination instruments, fall neatly into two groups with respect to their case lengths. Within very small margins, those pianos of the earlier group, ending with S/1783c, have the same case lengths and FF string lengths. In the second group, the case lengths are again the same but the lengths of the FF strings are chronologically subdivided into two groups, one with FF string lengths about 15mm shorter than those of the other.

The scaling of all the pianos by Stein is stretched in the treble. The strings of the top note, f"', are longer than required for a scaling based on the length of c" and an octave ratio of 1 : 1.95 by an amount ranging from half a semitone to more than two semitones. The extent of the stretching varies irregularly although one semitone is the norm.

Under Nannette Streicher the general design of the pianos produced by the firm diversified and various innovations were made. The most obvious of these is the enlargement of the compass, giving the client a choice of ranges. But the general lack of uniformity in the design of the few surviving instruments made by the Streicher firm at the beginning of the nineteenth century suggests that this period was one of experimentation and rapid change. There is only one pair of pianos, of about 1804, (S/c.1804a and S/c.1804b) with almost identical scaling patterns and case lengths. Although the two surviving instruments of 1814 also have the same scalings they have different case lengths. The same is true of the two 1819 instruments.

Pianos by Stein and Streicher
Case length, FF and c" string lengths, likely octave ratio, number of semitones of bass foreshortening and treble stretching

Piano	Case length mm	Case length *Zoll*	FF string length mm	FF string length *Zoll*	c" string length mm	c" string length *Zoll*	Octave ratio R	No. of semitones fore-shortening at FF	No. of semitones treble stretching at top note
Augsburg	(Augsburg *Zoll*)								
S/1781	1830	74.15	1462	59.23	306	12.40	2	15½	1½
S/1782	2111	85.53	1713	69.41	299	12.12	1.95	11	½
S/1783a	2117	85.78	1711	69.33	297	12.03	1.95	11½	1
S/1783b	2114	85.66	1712	69.37	296	11.99	1.95	11	1
S/1783d	2112	85.58	*1719*	*69.95*	*305*	*12.36*	*1.95*	*11½*	*1*
S/1783e	2127	86.18	1700	68.88	297	12.03	1.95	12	1
S/1783f	2123	86.02	n/o		n/o				
S/1784	2122	85.98	1701	68.92	295	11.95	?		
S/1786	2125	86.10	1701	68.92	302	12.24	1.95	11½	2
S/1788a	2124	86.06	1705	69.08	296	11.99	1.95	11	1
S/1788b	2125	86.10	*1698*	*68.80*	*290*	*11.75*	*1.95*	*12*	*1*
S/1790	2126	86.14	1684	68.23	292	11.83	1.95	11	1
S/1792	2122	85.98	*1688*	*68.40*	*284*	*11.51*	*2*	*12*	*1½*
S/1793	2128	86.22	1685	68.27	285	11.55	2	12	2
Vienna	(Viennese *Zoll*)								
S/c.1796/27	2115	80.37	1673	63.57	282	10.72	2	12	2
S/c.1800	2112	80.25	*1679*	*63.80*	*282*	*10.72*	?		
S/c.1804a	2116	80.40	1678	63.80	279	10.60	2	12	1½
S/c.1804b	2109	80.13	1680	63.83	282	10.72	2	12	1½
S/1805/649	2121	80.59	*1716*	*65.20*	*290*	*11.02*	*1.95*	*10½*	*0*
S/1805/673	2150	81.69	*1782*	*67.71*	*301*	*11.74*	*2*		
S/1807/733 C	2409	91.53	1892	71.89	285	10.83	2	14½	0
S/1808/764 C	2430	92.33	1884	71.58	273	10.37	2	14	0
S/1811/902	2257	85.76	*1757*	*66.76*	*267*	*10.14*	*2*	*10½*	*1*
S/1813/961	2248	85.41	1740	66.11	273	10.37	2	11	0
S/1814/1031	2257	85.76	1772	67.33	267	10.14	2	10	0
S/1814/1060	2287	86.90	1771	67.29	269	10.22	2	10	0
S/1816/1117	2275	86.44	*1827*	*69.42*	*265*	*10.07*	*2*	*9½*	*-1*
S/1819/1415	2332	88.61	1867	70.94	265	10.07	2	9½	0
S/1819/1425	2323	88.26	1870	71.05	269	10.22	2	9½	0
S/1820/1486	2327	88.42	1860	70.67	268	10.18	2	9½	1
S/1820/1550			1860	70.67	272	10.33	2	9½	2
S/1823/1756 C	2467	93.74	1910	72.57	270	10.26	?2	(13	½)
S/1826/2053	2290	87.01	1863	70.79	282	10.72	2	10	1
S/1827/2185	2315	87.96	1813	68.89	280	10.64	?2	(13	½)
S/1828/2237	2316	88.00	1811	68.81	283	10.75	?2	(10½	½)
S/1830/2383	2323	88.26	1811	68.81	279	10.60	?2	(10½	½)

Table 55

Four instruments, S/1807/733, S/1811/902, S/1816/1117 and S/1819/1415, all have identical stringing schemes from FF to C#, starting with gauge 8/0 at FF, and yet have very different lengths for FF, respectively 1892mm, 1757mm, 1827mm and 1867mm. In the bass the predetermined stringing scheme appears to have been applied independently of the scaling design.

During this same experimental period, that is from 1804 to 1820, the Streicher firm did not stretch the scaling in the treble, if we assume a Pythagorean scaling based on the length of c".

Evidence that the instruments of the Streicher firm were made in series begins to emerge in the 1820's. The last three pianos on the list in table 55, for instance, were clearly made to the same pre-determined design. They have the same case lengths and the scaling patterns and have identical string gauge schemes stamped on the wrestplank.[213] In contrast with the pianos of the previous period the treble scaling is stretched.

Other variables, including range and the extent of triple stringing appear in some cases to be related to the overall scaling design. This is shown in table 56 in which the sounding lengths of the FF and c" strings are given as characteristic of the scaling in the bass and the treble respectively. The consistencies provide some evidence that the pianos were produced in series. The two 1814 instruments, for instance, again form a pair, as do two pianos of 1819, three of 1820 and possibly those of 1827 and 1828.

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213 S/1827/2185 has four extra notes in the treble, from f# "" to a"", and these notes are marked for one extra, thinner gauge, gauge 2. The other two pianos have the more normal range of FF to f"".

Pianos by Streicher
Range, triple stringing and scaling design

Code	Range	Bichord/ Trichord transition	String length FF (mm)	String length c" (mm)
S/1807/733	CC-f""	D/D#	1892	285
S/1808/764	CC-f""	BB/C	1884	275
S/1811/902	FF-f""	C/C#	1750	267
S/1813/961	FF-f""	C/C#	1740	273
S/1814/1031	FF-f""	AA#/BB	1772	266
S/1814/1060	FF-f""	AA#/BB	1772	265
S/1816/1117	FF-f""	AA#/BB	1827 (n/o)	265
S/1819/1415	FF-f""	AA#/BB	1867	265
S/1819/1425	FF-f""	AA#/BB	1870	269
S/1820/1486	FF-f""	AA#/BB	1860	267
S/1820/1550	FF-f""	AA#/BB	1860	272
S/1820/1563	FF-f""	AA#/BB	1860*	267*
S/1823/1756	CC-f""	DD#/EE	1910	270
S/1826/2053	FF-f""	EE/FF	1863	282
S/1827/2185	FF-a""	EE/FF	1813	281
S/1828/2237	FF-f""	EE/FF	1811	283
S/1830/2383	FF-f""	AA/AA#	1812	279

Table 56

The pianos of Hofmann: case length, bass foreshortening and treble stretching

No piano by Hofmann exceeds FF in the bass. With the exception of three instruments, which were probably intended for a higher pitch, the case lengths of the instruments with compasses up to f''' or g''' average 2086mm, varying only 4mm either side.[214] The lengths of the FF strings of these instruments and that of H/c.1805, which extends up to c'''', vary between 1625mm and 1638mm.

H/c.1805 owes its slightly longer case, at 2106mm, to a superficially different design: the vertical case sides at the front are extended further forward than usual so that the front lid flap can fall between them. In the earlier instruments, the front flap falls over the case sides which slope downwards at the front. This instrument shows other more important features which distinguish it both from the earlier pianos and from the two later ones. There are, for instance, two metal gap spacers instead of the single wooden gap spacer previously used by Hofmann. But the case length and the FF string length are features retained from the design of the earlier pianos.

H/c.1815, of six octaves, has a later soundboard so that the length of the FF string, now 1774mm, is unreliable. Nonetheless, it can not be more than 10mm different in length from the original. The bridge is the original one and its position is determined in the

214 H/c.1795g and H/c.1795h do not conform to the pattern but are discussed below in the chapter on pitch.

bass by a mortice in the spine. The bass end of the bridge was re-inserted into this mortice when the new soundboard was installed. The bridge is also sawn out rather than bent in the bass so that the positions of the bridge pins in the bass can hardly have changed.

The present length of FF and the case length of 2370mm show that H/c.1815 was designed according to a new plan. Nonetheless, the internal construction is of the same type as that of the earlier pianos by Hofmann except that the dimensions of the frame members and of the bellyrail are far greater than in the earlier instruments.

H/c.1820, with a case length of 2320mm and an FF string length of 1750mm, is also clearly built according to a new plan which is neither related to the design of the earlier instruments nor to that of H/c.1815. Although the interior construction is again conceived along the same lines as the previous instrument, the case shape, with a bentside which curves round in a double S-shape from the tail all the way to the front of the piano, is a new departure. The case lengths and the lengths of the FF strings of Hofmann's pianos are summarised in table 57.

Pianos by Hofmann pianos
Case length and FF string length

	Case length (mm)	Length of FF (mm)
Pianos up to f''' or g'''	2086 (2082-2096)	1631 (1624-1638)
H/c.1805	2106	1631
H/c.1815	2370	1774*
H/c.1820	2320	1750

* This length is not original but can not have been less than 10mm longer or shorter.

Table 57

In Hofmann's pianos with a range of less than six octaves the foreshortening at FF varies between 12 and 14 semitones whereas the absolute length of the FF string varies very little, suggesting that Hofmann used the absolute length of FF as a fixed part of the design rather than relating it to the changing length of c". In all those instruments with gauge markings, even including the longer six-octave piano, H/c.1820, which has considerably longer bass strings, the stringing schemes are the same in the bass from FF as far as E, starting with gauge 7/0. While the FF string length and the case length may thus be interdependent parts of the design, the stringing scheme in the bass remained the same irrespective of the bass scaling.

Hofmann's pianos show little consistency in the scaling pattern in the extreme treble. Assuming Pythagorean scaling, the string of the top note is too short in two pianos (H/c.1785b and H/c.1820), while in others the top string is stretched by more than two semitones. The inconsistency of the treble stretching is illustrated by three instruments, H/c.1795a, H/c.1795b and H/c.1795c, which appear to have been built to the same scaling design and have identical stringing schemes. The strings of the top note, g"', are stretched to appreciably different degrees, by $1^1/_2$, $^1/_2$ and 1 semitones, or, in absolute terms, they are stretched by 8mm, 3mm and 6mm respectively. These differences are probably due to the fact that the treble end of the bridge was bent to shape as it was glued onto the soundboard.

The pianos of Walter: case length, bass foreshortening and treble stretching

The scalings of Walter's pianos do not approximate a geometric progression very closely. In comparison to a Pythagorean scaling, however, the scalings of all but one of them (W/c.1820) show scale stretching in the treble in relation to the length of c", ranging from less than a semitone to two semitones.

All of Walter's grand pianos show foreshortening in the bass varying at FF from $11^{1}/_{2}$ to $12^{1}/_{2}$ semitones in relation to the length of c" in comparison to a Pythagorean scaling. At FF, five of the 18 pianos measured have string lengths which are foreshortened by exactly 12 semitones and in only one is the FF string length foreshortened by more than 12 semitones (W/c.1782a). W/c.1820 is exceptional. With a range down to CC (all the others only go down to FF) the FF string length is foreshortened by $10^{1}/_{2}$ semitones and that of CC by 15 semitones.

Some of Walter's pianos form pairs or fall into groups of similar instruments with respect to scaling and case length (table 58). W/c.1782a and W/c.1782b form a pair, given some allowance for variation in case length. W/c.1782d probably also belongs to this group although when the new soundboard was installed, apparently in about 1820, the bridge was repositioned, thus significantly altering the scaling.[215] The case of W/c.1782e has

215 See Michael Latcham, 'Authenticating and dating the pianos of Anton Walter', *Restaurieren Renovieren Rekonstruieren. Methoden für Hammerklaviere*, Vienna 1997, 67-82.

been shortened. When it was lengthened in 1937 a new soundboard was installed. The three pianos of c.1785 have almost exactly the same case length. W/c.1785b has a new soundboard of recent date. The differences between the scalings of the two remaining pianos of this group can be explained by the hypothesis that W/c.1785c was intended for use at a higher pitch than W/c.1785a.[216]

W/c.1800a and W/c.1800b also form a pair. W/c.1800d may belong to this group although the soundboard is a replacement of unknown date so that the string lengths are untrustworthy. The latter is also true of W/c.1815a which, although it does not have a new soundboard, has been extensively altered. The remaining pianos of c.1815 in table 58 form a group with case lengths averaging 2185mm, FF string lengths averaging 1742mm, both varying 5mm either side, and c'' string lengths averaging 285mm, varying 3mm either side. The shorter scalings of W/c.1815g can be explained by the hypothesis that this piano was also intended for a higher pitch.

216 This and W/c.1815g will be dealt with in the appropriate chapter below.

Pianos by Walter
Case length, FF and c" string lengths

Piano	Case length		FF string length		c" string length	
W/	mm	*Zoll*	mm	*Zoll*	mm	*Zoll*
c.1782a	2225	84.54	1775	67.44	303	11.51
c.1782b	2206	83.82	1771	67.29	296	11.25
c.1782d	2186	83.06	n/o		n/o	
c.1782e	n/o		n/o		n/o	
c.1785a	2164	82.22	1761	66.91	297	11.28
c.1785b	2165	82.26	n/o		n/o	
c.1785c	2167	82.34	1725	65.54	283	10.75
c.1790	2177	82.72	1767	67.14	294	11.17
c.1795	2169	82.41	1763	66.99	300	11.40
1796	2165	82.26	1769	67.21	287	10.90
c.1800a	2171	82.49	1738	66.04	282	10.71
c.1800b	2172	82.53	1737	66.00	282	10.71
c.1800c	2163	82.19	*1752*	*66.57*	*290*	*10.02*
c.1800d	2176	82.68	*1734*	*65.88*	*277*	*10.52*
c.1800e	2166	82.30	1735	65.92	284	10.79
c.1805a	2148	81.62	1721	65.39	289	10.98
c.1805b			1741	66.15	279	10.60
c.1815a	2171	82.49	*1751*	*66.53*	*273*	*10.37*
c.1815b	2182	82.91	1737	66.00	282	10.71
c.1815c	2188	82.14	1742	66.19	289	10.98
c.1815d	2186	82.06	1742	66.19	285	10.83
c.1815e	2189	82.17	1741	66.15	285	10.83
c.1815f	2180	82.83	1747	66.38	285	10.83
c.1815g*	2184	82.98	1718	65.28	267	10.14
c.1817	2225	84.54	1745	66.30	285	10.83
c.1820*	2345	89.10	1747	66.38	270	10.26

Table 58

Case length, bass foreshortening and treble stretching: summary and conclusion

On the basis of the surviving instruments it appears that the case length and the length of the strings for the note FF were starting points for the piano designs of Stein and Hofmann. The same is probably true of the pianos of Walter. There is not enough evidence to draw a similar conclusion about the pianos of Streicher made between 1805 and 1820.

Nannette Streicher's pianos appear to be exceptional in that from 1805 to 1820 there is no stretching of the treble scaling. But the majority of makers, who did stretch the treble scaling, did so without any apparent consistency, suggesting that it is unlikely that any consideration of the relationship between scaling and sound lies behind the lengthening of the strings of the top notes.

Finally, not only do the stringing schemes of the pianos of both Streicher and Hofmann appear to have been a predetermined part of the design but they also appear to have been chosen independently of the bass scaling and the case lengths.

Expalnations for bass foreshortening and treble stretching

The immediate explanation for bass foreshortening is obvious. If the scaling of a piano with a c" string length of 282mm, normal in Vienna in about 1790, were continued down to FF and if, at the same time, an octave ratio of 1 : 2 were maintained the length of the FF string would be 3380mm. A piano with such long bass strings would have to be longer than four meters.

No reason for treble stretching, however, is immediately apparent. Eighteenth-century builders were aware that owing to the process of drawing wire, in which it becomes work-hardened, thinner strings have a relatively higher tensile strength in comparison to thicker ones. This phenomenon, known today as tensile pick-up, will have enabled builders to lengthen the treble strings without increasing the risk of them breaking.[217] But this in itself does not explain why the treble strings were stretched, only that stretching them was possible.

The lengthening of the treble strings can be explained as a practical expedient. In the extreme treble the curve of the bridge was exaggerated to avoid the stiff front edge of the soundboard. In Viennese and southern German pianos made before about 1810, there appears at first sight to be enough space on the soundboard in front of the tip of the bridge to continue a Pythagorean scaling

217 See Martha Goodway and Jay Scott Odell, 'The Metallurgy of 17th- and 18th-century music wire', *The Historical Harpsichord*, ed. Howard Schott, 2, Stuyvesant, N.Y., 1987, 60-2 for a discussion of tensile pick-up. Goodway and Odell quote two eighteenth century sources, Corrette and Adlung, who both remarked on the fact that thinner strings are stronger than thicker ones.

or even a tapered scaling to the top note. But the front edge of the soundboard is stiffened by an 'apron', a broad flat piece of wood glued underneath, restricting the area of free soundboard. Pianos of the Viennese and southern German traditions differ from harpsichords and from English pianos in that the soundboard overhangs the bellyrail. The soundboard is also not glued to the bellyrail in the treble and sometimes not glued to the bellyrail at all except at the liners and in the middle of the compass.[218] The treble half of the front of the soundboard would thus be left unsupported without the apron.

Stretching of the treble scaling

Stretching of the treble scaling in the pianos of Hofmann

In the following discussion five pianos by Hofmann are used to illustrate how makers solved the problem of keeping the bridge in the extreme treble away from the stiff front edge of the soundboard.

Of the five, H/c.1785c has the longest scaling with a c" string length of 293mm. The top note is f'". No stretching of the treble scaling is necessary to keep the bridge at a good distance from the edge of the apron (ill. 15 and graph 52).

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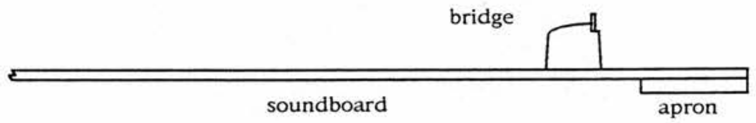
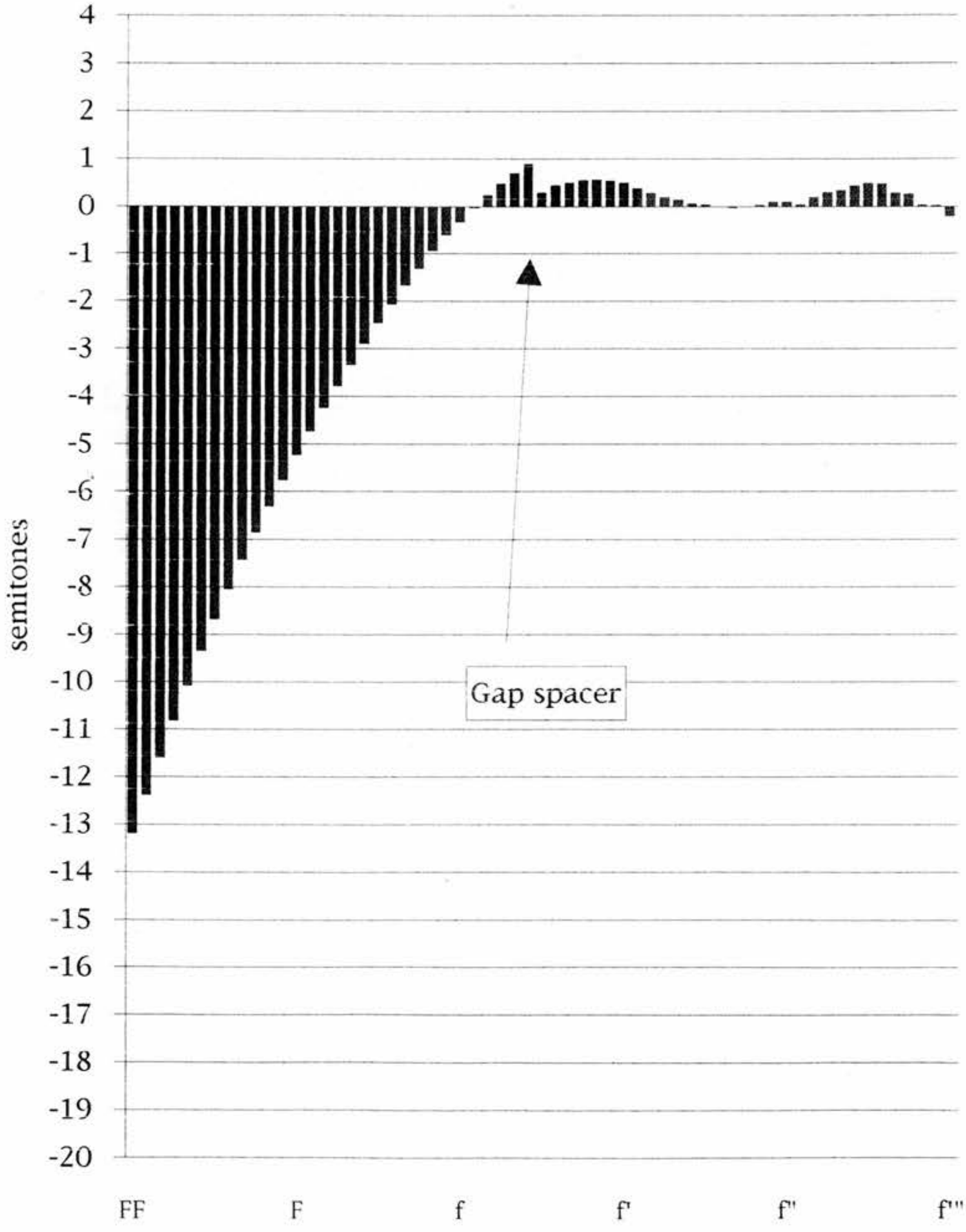
218 This is the case in the pianos by Schantz. Those of Stein, Streicher, Walter and Hofmann generally have the soundboard glued to the belly rail from the middle of the compass downwards.



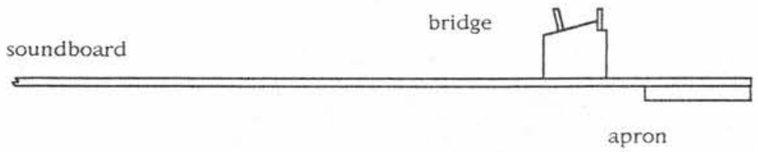
ill. 15 The position of the bridge in relation to the soundboard apron in H/c.1785c

Grand Piano Ferdinand Hofmann (H/c.1785c)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



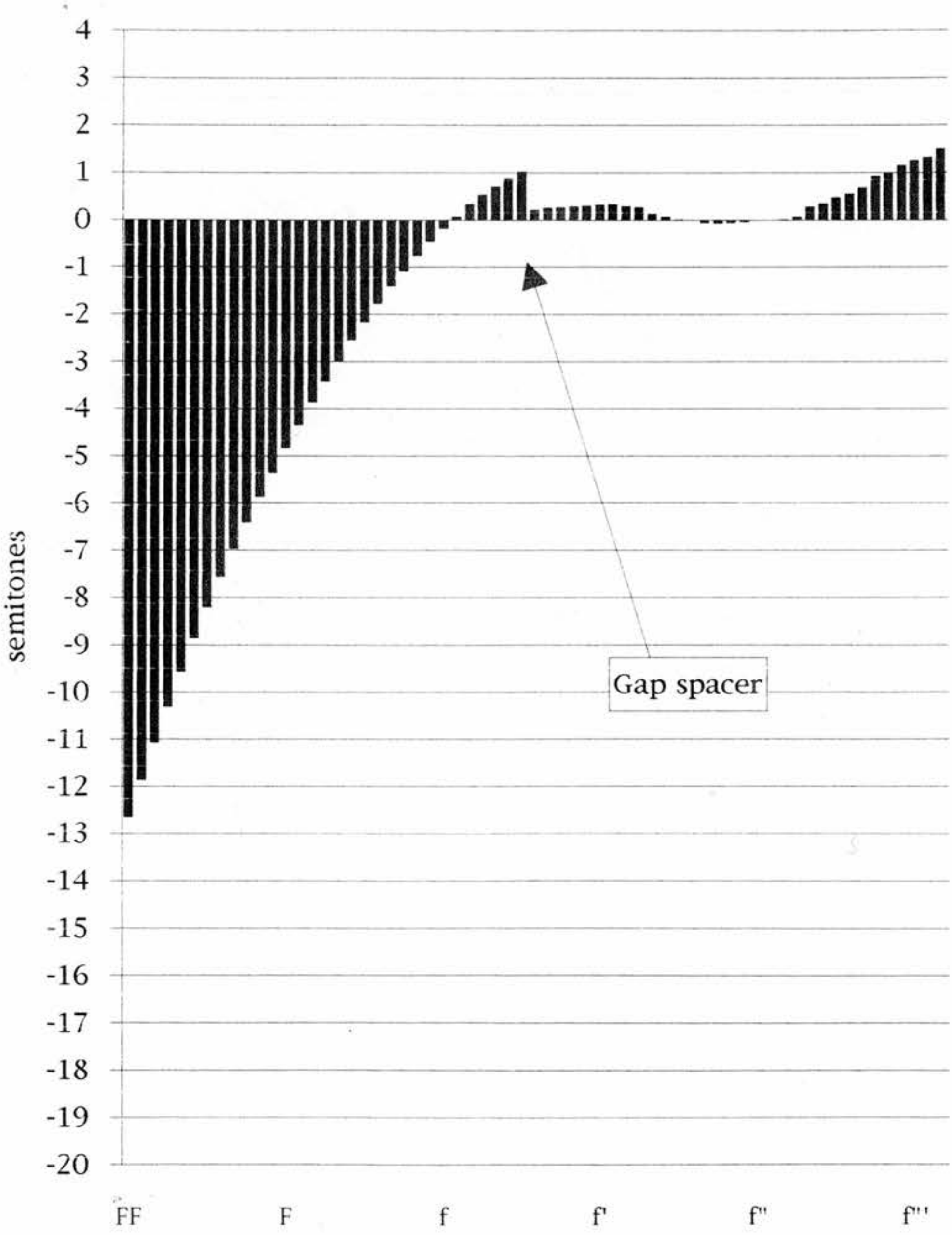
graph 52

The scaling of H/c.1795a is shorter than that of H/c.1785c, with the length of the c" string reduced to 284mm, and the range is extended to g'". Hofmann exaggerated the curve of the bridge in the treble such that at g"' the bridge is at about the same distance from the apron as at f"' in H/c.1785c (ill. 16). The strings for the top note are stretched by $1^1/_2$ semitones (graph 53).



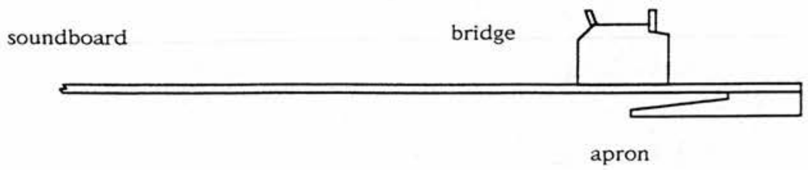
ill. 16 The position of the bridge in relation to the soundboard apron in H/c.1795a

Grand Piano Ferdinand Hofmann (H/1795a)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



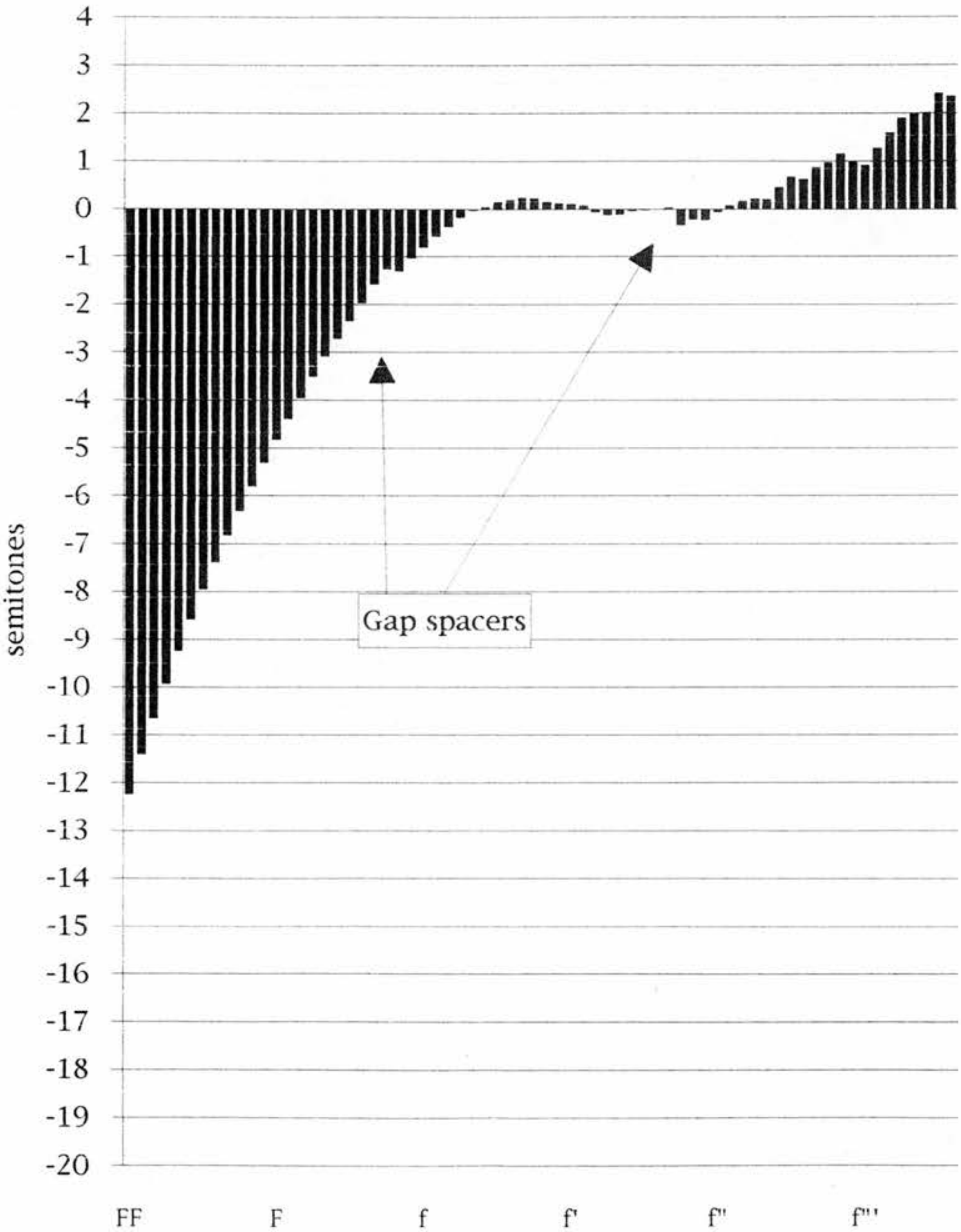
graph 53

In H/c.1805, the compass is extended further to c"" and the scaling is shorter still, with the c" string length at 277mm. In the treble the apron is under-cut so that only part of its surface is glued to the underside of the soundboard (ill. 17). The curve of the bridge is again exaggerated in the extreme treble such that the top strings are stretched by more than 2 semitones, that is, by 10mm (graph 54). By undercutting the apron and by stretching the treble scaling the distance between the treble end of the bridge and the stiffened part of the soundboard is kept the same as in the two earlier pianos.



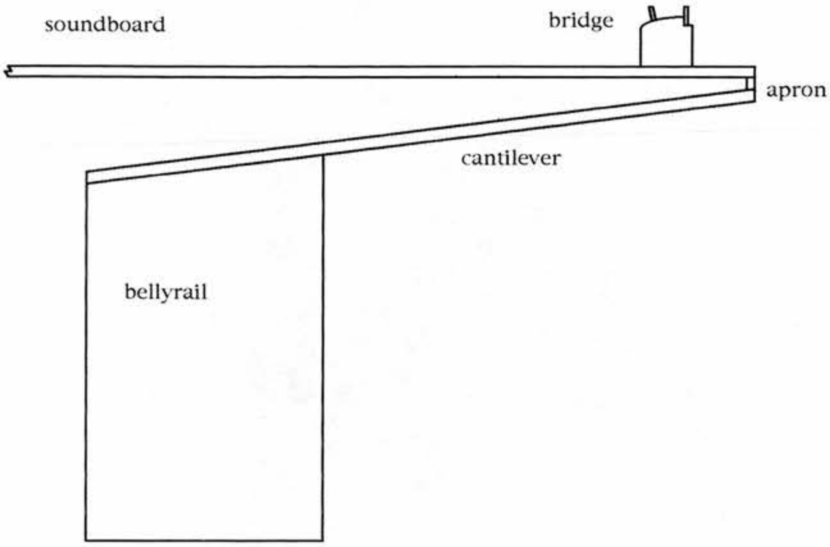
ill. 17 The position of the bridge in relation to the soundboard apron in H/c.1805

Grand Piano Ferdinand Hofmann (H/c.1805)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



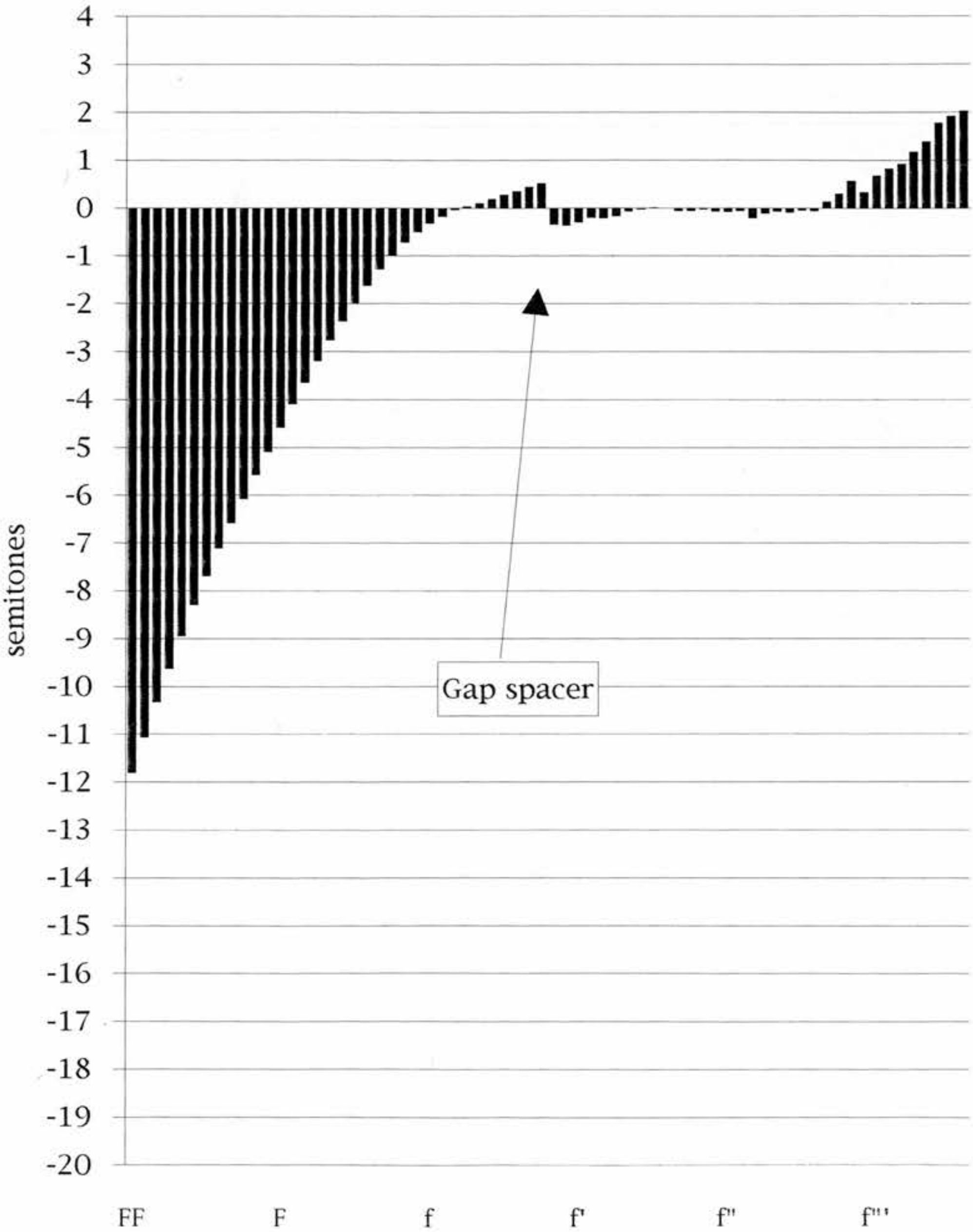
graph 54

In H/c.1795g the scaling is shorter still, with a c" string length of 267mm. The compass, FF-c"", is however the same as in H/c.1805. In H/c.1795g the apron is only 2mm wide in the treble (ill. 18). The support which the front edge of the soundboard would otherwise lack with such a narrow apron is provided by a thin, flat piece of wood acting as a cantilever. As usual in the treble, the soundboard is not glued to the bellyrail. The top surface of the bellyrail slopes up towards the player. The cantilever is glued to this angled surface for a width of about 150mm in the extreme treble such that it rises to meet the underside of the front edge of the overhanging soundboard. There the cantilever is glued to the soundboard with the very small apron (about 2mm by 2mm) sandwiched between (ill. 18). At no point does the cantilever touch the soundboard or its ribs. This unusual solution to the problem of the treble construction, together with treble stretching amounting to two semitones (6 mm) in the extreme treble, keeps the bridge away from the stiffened front edge of the soundboard at the top note (graph 55).



ill. 18 The position of the bridge in relation to the soundboard apron in H/c.1795g

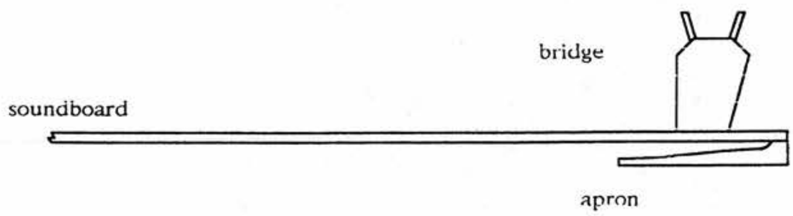
Grand Piano Ferdinand Hofmann (H/c.1795g)
Deviation of the string lengths from a
Pythagorean scale based on the length of c"
expressed in semitones



graph 55

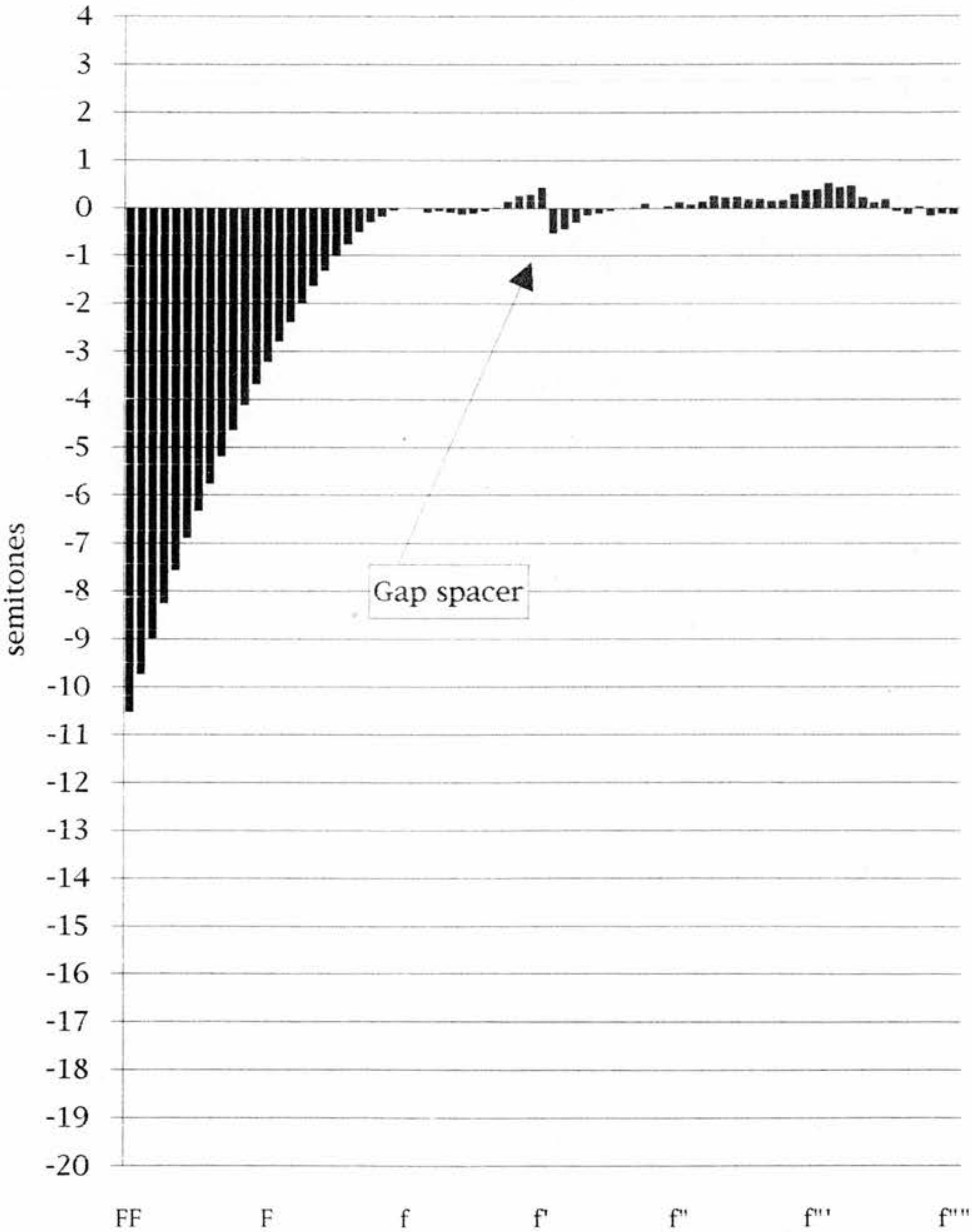
The treble scaling of H/c.1820 is not stretched at all (graph 56) although the compass is now extended to f"". The length of c" is 3mm shorter than in H/c.1795g at 270 mm. The apron is only glued to the soundboard for a few millimetres along the very front edge in the treble in a similar but more drastic manner to that in H/c.1805. At the same time, the bridge is undercut on the player's side in the extreme treble (ill. 19). This combination leaves the bridge on free soundboard without stretching the treble scaling.

The various methods that Hofmann employed to keep the bridge on free soundboard were complemented by narrowing the gap between the front edge of the soundboard and the wrestplank through which the hammers rise to strike the strings. This gap has to be wide enough not only to allow the hammers to rise but also to contain the moderator and the damper mechanism. The string of the top note of H/c.1820, f"", is less than half the length of the string of the top note on H/c.1785c, f"'. But by narrowing the moderator batten, the damper jacks and their housing, and by making the hammers less broad from front to back, Hofmann could reduce the size of the gap considerably. The various factors are quantified in table 59.



ill. 19 The position of the bridge in relation to the soundboard apron in H/c.1820

Grand Piano Ferdinand Hofmann (H/c.1820)
Deviation of the string lengths from a
Pythagorean scale based on the length of c''
expressed in semitones



graph 56

A comparison of the treble scalings of five Hofmann pianos

Piano	Top note	Length of of top string (mm)	Length of c'' (mm)	Treble Stretching (semitones)	Width of gap at top (mm)
H/c.1785c	f'''	108	293	0	60
H/c.1795a	g'''	102	284	$1^1/_2$	61
H/c.1805	c''''	77	277	2	52
H/c.1795g	c''''	73	267	2	48
H/c.1820	f''''	50	270	0	35

Table 59

Stretching of the treble scaling in the pianos of Hofmann: summary

With the earlier, five-octave instruments, there is no problem in keeping the scaling Pythagorean in the treble and the top end of the bridge on free soundboard, even though the full width of the apron is glued under the soundboard in the extreme treble. Problems only appear to have arisen as the compass was enlarged in the treble to include higher notes and therefore shorter top strings. At the same time, there was a tendency to shorten the scaling, making the top strings shorter still. Apparently in order to avoid having the bridge on the stiffened front part of the soundboard the scaling was stretched, the bridge and the apron were undercut and the width of the gap was decreased.

Stretching of the treble scaling in the pianos of Stein and Streicher

In Stein's pianos, all of which have a compass from FF to f''', the treble end of the bridge is glued on an area of free soundboard. There is no undercutting of the apron and the treble scaling is stretched by one to two semitones, if we assume an octave ratio of 1 : 1.95. It would have been quite possible for Stein to have kept the bridge on free soundboard without stretching the treble scaling. It may be that he preferred placing the bridge well away from the stiff front edge of the soundboard or that he wanted to take advantage of the strength of the thinner treble strings. Conversely, he may have wished to have the treble strings as close to their breaking point as the strings lower down.

Nannette and Matthäus Andreas Stein extended the compass from f''' to g''' in about 1796 (S/c.1796/27). The additional two notes brought the treble end of the bridge closer to the front edge of the soundboard. When Nannette Streicher extended the compass to c'''', in S/c.1804a and S/c.1804b the tip of the bridge came close to the front edge of the soundboard. In order to accommodate the bridge Nannette Streicher had to make a cut-out in the broad flat moulding which runs along the front top edge of the soundboard. No attempt was made to avoid the apron glued directly underneath.

The new design of S/1807/733 includes an extension of the compass to f'''' and undercutting of both the apron and the bridge, leaving 11mm of free soundboard in front of the bridge. There is no stretching of the scaling in the treble and the strings for the notes around c'''' are even short by a semitone. The gap in the treble is only 35mm wide. The design of the treble scaling of S/1808/764, which also has the range CC- f'''', is very similar. Without compromising the position of the bridge with regard to the stiff front edge of the soundboard, all possible means appear to have been used to avoid treble stretching in these two instruments.

In about 1820 the design of Streicher's pianos appears to have changed with respect to treble stretching. In S/1823/1756 the treble gap is slightly wider (40mm) and the bridge is kept on free soundboard by stretching the scaling by a semitone in the extreme treble.

Stretching of the treble scaling in the pianos of Walter

In all but the very earliest of his instruments the bridges of Walter's pianos are sawn rather than bent. The treble end of the bridge is always well-positioned on free soundboard. In the earlier pianos this is achieved without recourse to undercutting either the apron or the bridge but simply by stretching the scaling in the treble by between one and two semitones. The later, six-octave pianos of c.1815 and the piano of six-and-a-half octaves, W/c.1820 show little or no treble stretching. Instead, the apron is undercut. There is only one piano by Walter (W/c.1815a) known to the author in which the bridge is partly glued to the soundboard where the latter is stiffened by the apron underneath. This is probably one of the results of the major repairs this instrument has undergone. The apron is not undercut, as it is in other similar instruments, and appears to be later.

Stretching of the treble scaling: summary

Hofmann appears to have used a variety of expedients to solve the layout problems involved in keeping the bridge on free soundboard as the treble strings became shorter. One of these was to stretch the lengths of the treble strings. The Streicher firm seems to have made various compromises to solve these problems before finding a satisfactory solution in 1820. Walter maintained a clear design throughout his career, keeping the bridge on free soundboard and stretching the treble scaling in his earlier instruments with the thinner, stronger gauges, as Stein had done before him. It is as if Stein and Walter wanted to use thinner strings and compensated for their superior strength by stretching the treble scaling while Hofmann and Streicher had to stretch the treble scaling for reasons of design and compensated for this by using thinner strings.

The English influence and the divided bridge

Foreshortening of the bass scaling is a practical solution to the problem of excessively long keyboard instruments and was universally used from the late eighteenth century onwards. The extent to which the treble scaling is stretched varied within a single tradition and even within the work of a single maker. The stretching of the treble scaling can perhaps be best understood as a practical solution to the problem of keeping the bridge on free soundboard. Different practical solutions were also found for the problem of the interruption in the scaling caused by the gap spacer. The deviations from a geometric progression involved in foreshortening, treble stretching and the incorporation of a gap spacer thus all have to do with solutions to practical problems. In contrast, the application of the divided bridge can be considered to be derived from a theory developed to improve the scaling rather than as a practical response to a scaling problem.

The English consistently used the divided bridge at the end of the eighteenth century and there can be little doubt that it was English influence which brought the divided bridge to Vienna, both directly and indirectly through the French tradition. As an introduction to the divided bridge it is convenient here to consider the English influence on the Viennese makers.

The English influence

Although the differences between the English and the Viennese schools of piano building are often rightly emphasised, the influence of the late eighteenth-century English makers like Broadwood and the early nineteenth-century French piano makers like Erard on the German-speaking builders should not be underestimated. On the 14th of December 1803 Georg Griesinger wrote from Vienna to the publishers *Breitkopf und Härtel* in Leipzig:

> 'The brothers Erard of Paris have made a present of a piano made of mahogany to Beethoven (like they did earlier to Haydn). He is so enchanted with it that, by comparison, he regards all those made here as rubbish. Because you are heavily involved in instrument dealing it will not be uninteresting for you to hear that Beethoven had already criticized the local instruments before. He said that they were wooden

> and that they get one into the habit of a small, weak touch. Beethoven being Beethoven may be right, but how many players are there like him? The keyboard of the Parisian piano is, even on Beethoven's admission, not as supple and elastic as in the Viennese pianos. But that is a trifle to a master like Beethoven. Presumably the instrument makers here will try to study and acquire the advantage of the brothers Erard. I therefore want to try to impress this on Streicher, even though he was not contented with the one Haydn owns...'[219]

Andreas Streicher, Nannette's husband, was originally a harpsichord player and teacher. Initially he looked after the financial side of the firm but gradually took more than a business interest in piano building. He appears to have realised that it could indeed be to his firm's advantage to study the English and French pianos. On March 11th 1806 he wrote to Härtel:

> 'You say you are anxious about my opinion of the English and French pianos and I may say right away that I have absolutely and always preferred the tone of those instruments above all others. But the construction of the keyboard is so opposed to the build

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219 '*Die Brüder Erard in Paris haben dem Beethoven (wie früher dem Haydn) ein Geschenk mit einem Fortepiano von Mahony gemacht. Er ist so davon bezaubert dass er alle hiesigen Arbeiten für Quark dagegen hält. Da Sie einen starken Instrumentalhandel treiben so wird es Ihnen nicht uninteressant seyn zu hören dass Beethoven den Ton der hiesigen Fortepiano schon früher immer als hölzern tadelte, desgleichen dass sie ein kleines schwaches Spiel gewöhnen. Beethoven als Beethoven mag recht haben; aber wie viele Spieler giebt es wie Er? Die Tastatur des Pariser Fortepiano ist selbst nach Beethovens Geständnis nicht so geschmeidig und elastisch wie die der Wiener Fortepiano. Einem Meister wie Beethoven ist das aber eine Kleinigkeit. Vermutlich werden die hiesigen Instrumentenmacher den Brüdern Erard ihren Vortheil anzulernen suchen und ich will deswegen auch in Streicher dringen, ob er gleich mit dem welches Haydn besizt, nicht zufrieden war...*' Otto Biba (ed.), *"Eben komme ich von Haydn..." Georg Griesingers Korrespondenz mit Joseph Haydns Verleger Breitkopf & Härtel 1799-1819*, Zürich 1987, 216.

of the hand that I can hardly think of anything more inappropriate; the whole action is as little durable as it is fitting for a true performance. The future will persuade you that I am certainly not being partial...

...I have sought to unite this tone with the action to which we are accustomed, and if I may trust the opinions of the best piano players and amateurs here, I have succeeded tolerably'.[220]

Both Andreas and Nannette Streicher knew Beethoven well and must have been familiar with the piano given to Beethoven in 1803.[221] Beethoven appears to have liked the pianos of the Streicher firm although he never owned one. Schantz, on the other hand, although he too had dealings with Beethoven, was more associated with Haydn and supplied him with a piano. Haydn and Schantz appear to have been business friends. Schantz was therefore probably well-acquainted with the piano by Erard given to Haydn in 1801.[222]

Some English and French traits copied by the Viennese were

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220 '*Sie sagen, daß Sie über mein Urtheil von den engl. und französ. Pf. begierig sind, und ich darf Sie im voraus versichern, daß ich immer und allezeit den ton dieser Instrumente allen anderen vorgezogen habe....; daß aber auch der Bau der Tastatur dem Bau dem Hand so ganz entgegengefetzt ist, daß sich schwerlich etwas zweckwidrigeres denken läßt, und daß die ganze Mechanik eben so wenig dauerhaft als zum wahren Vortrag passend ist. Die Zukunft wird Sie überzeugen, daß ich gewis nicht partheiisch bin,....Ich habe noch mehr gethan: ich habe diesen Ton mit unsere gewöhnlichen Mechanik zu vereinbaren gesucht, und wenn ich anders dem Urtheile der besten heisigen Clavier-Spieler und Liebhaber trauen darf, so ist es mir so ziemlich gelungen...*'.Wilhelm Lütge, 'Andreas und Nannette Streicher', *Der Bär, Jahrbuch von Breitkopf und Härtel*, 1927, 66.

221 Preserved in the Oberösterreichisches Landesmuseum, Linz.

222 For details on the piano by Erard given to Haydn see Horst Walter, 'Haydns Klaviere', *Haydn-Studien*, December 1970/4, 256-88 and especially 282-3.

purely decorative. One of these was the combination of mahogany for the external case with white key covers for the naturals, either of bone or of ivory. This combination was generally used by Viennese makers for their more expensive pianos from about 1785 onwards, for instance by Hofmann and a little later by Walter.[223] The earliest piano by Streicher of the more expensive type is dated 1805.[224] The less expensive pianos of the period have the case in walnut or cherry and the naturals with ebony key covers.[225]

Although the style of decoration obviously has no influence on the sound the presence of features typical of the French and English pianos of the period signifies that the Viennese makers must also have been aware of those other aspects of the English and French designs which were important to the sound. Those features to do with the stringing and scaling which appear to have made an impression on the Viennese makers include triple stringing throughout the compass, the use of arching gap spacers (and with them the use of the *una corda*) which take up no extra space in the string band, the notched bridge which allowed the two or three strings of each choir to be of the same length and, most

223 Of Hofmann's pianos, H/c.1785b, H/c.1790b, H/c.1795a and H/c.1795b have mahogany cases with bone naturals. W/c.1790, W/c.1800c, W/c.1800d, W/c.1800e and all the c.1815 pianos by Walter have mahogany cases and ivory naturals except W/c.1815f which has cherry veneer and ebony naturals.

224 S/1805/673.

225 Yew was sometimes treated in the same way as mahogany, for instance in S/c.1804a, W/c.1800a and K/4 (1796), that is, as a luxury wood but it is sometimes also found in the plainer instruments such as Sz/2 (c.1790) and Sz/5 (c.1795).

importantly, the divided bridge, with separate sections for the brass and iron strings.

The English influence and triple stringing

While the English had been using triple stringing throughout the compass since the 1780's it took until well into the nineteenth century for the Viennese to do the same. This may be because the English used an *una corda* stop already in the 1770's while in Vienna it only became standard in about 1810.[226] To function well the shift mechanism should either change the number of strings struck by all the hammers from two to one, or from three to two and possibly further to one. This can only be achieved if the piano is double or triple strung throughout. In a letter of 1802 Beethoven wrote to Court Secretary Nikolaus von Zmeskall to try to obtain a piano from Walter:

> 'You can give him [Walter] to understand that I will pay him 30 Kreuzer, even though all the others would charge nothing, but I will only give 30 Kreuzer on the condition that it is of mahogany, and I also want to have the register with one string, - if this has no effect, give him clearly to understand that I will choose one of the others'.[227]

226 The grand piano by Americus Backers of 1772 in the Russell Collection, University of Edinburgh, Cat. No. 24 is double strung throughout and has a *una corda* operated by a pedal.

227 '[...] *sie geben ihm also zu verstehen, daß ich ihm 30# bezahle, wo ich es von allen anderen umsonst haben kann, doch gebe ich nur 30# mit der Bedingung daß es von Mahagoni sei, und den Zug mit einer Saite will auch dabei haben, - geht es dieses nicht ein, so geben sie ihm unter den Fuß, daß ich einen unter den anderen aussuche,*[...] '. Alfr. Chr. Kalischer, ed., *Beethovens Sämtliche Briefe. Kritische Ausgabe mit Erläuterungen*, I, Berlin and Leipzig 1906-7, 105.

Beethoven had clearly seen or knew of an English or French instrument in mahogany with a *una corda* stop and was impressed by both. But Walter seems not to have heeded Beethoven and only started using a *una corda* stop and triple stringing throughout the compass in about 1815. Streicher began earlier with the *una corda* stop, in the piano of 1807, operated by a knee lever. The instrument was not triple-strung in the extreme bass, however, and owing to the present condition of the piano it is not clear if the intention was to use the shift pedal to obtain a true *una corda.* It is certainly not possible now and there was probably never enough room between the choirs of strings to move the action far enough for the hammers to strike only one string of each choir. The intention was probably *due corde* except in the double-strung bass where a *una corda* was inevitable. Table 60 presents the extent of triple stringing in the pianos of the Streicher firm between 1804 and 1839.

Pianos by the Streicher firm
Range, back-pinning and triple stringing

Code	Range	No. of Notes	Bichord/ Trichord transition
S/c.1804a	FF-c""	68	all bichord
S/c.1804b	FF-c""	68	all bichord
S/1805/649	FF-c""	68	a'/a#'
S/1805/673	FF-c""	68	a'/a#'
S/1807/733	CC-f""	78	D/D#
S/1808/764	CC-f""	78	BB/C
S/1811/902	FF-f""	73	C/C#
S/1813/961	FF-f""	73	C/C#
S/1814/1031	FF-f""	73	AA#/BB
S/1814/1060	FF-f""	73	AA#/BB
S/1816/1117	FF-f""	73	AA#/BB
S/1816/1147	FF-f""	73	AA#/BB
S/1816/1183	FF-f""	73	AA#/BB
S/1819/1415	FF-f""	73	AA#/BB
S/1819/1425	FF-f""	73	AA#/BB
S/1820/1486	FF-f""	73	AA#/BB
S/1820/1550	FF-f""	73	AA#/BB
S/1823/1756	CC-f""	78	DD#/EE
S/1826/2185	FF-f""	73	all trichord
S/1827/2185	FF-a""	77	all trichord
S/1828/2227	FF-f""	73	all trichord
S/1828/2237	FF-f""	73	all trichord
S/1830/2383	FF-f""	73	AA/AA#
S/1837/2991	CC-g""	80	DD#/EE
S/1839/3299	CC-g""	80	EE/FF

Table 60

The English influence and the gap spacer

In her experimental piano of 1805 (S/1805/649) Streicher used English-style gap spacers. The gap spacers in all her other pianos built before at least 1835 are of the traditional type occupying the space in the string band allotted to one choir of strings. Walter also used English-style gap spacers in his pianos from about 1815 onwards. His earlier gap spacers also took up no extra space in the string band but are not derived from the English tradition. They run under the strings rather than arching up over the gap and have a slot for the damper jack of the damper for the strings immediately to the right and make the incorporation of the *una corda* impossible. The idea of a gap spacer which does not interrupt the scaling curve appears to pre-date English influence in Vienna while the idea of using an arching gap spacer in conjunction with a *una corda* does seem to have come from England through France.

The English influence and equal string lengths

Because the bridge pins normally stand in the same line as the line of the bridge, the two (or three) strings of each choir have slightly different lengths. This is especially noticeable in the tenor where the angle of the bridge is at its steepest. In order to equalise the lengths of the strings of each choir the English and French makers notched the bridge and positioned the three bridge pins of each choir in a line parallel to the front edge of the soundboard rather than parallel to the line of the bridge.

The Viennese were slow to adopt the notched bridge. While all the known grand pianos by the Broadwood firm, going back to 1787, have equalised string lengths the earliest known pianos by Streicher and Walter with this feature are of 1807 and about 1815 respectively.[228] Streicher and Walter, once having started to use the notched bridge, continued to do so. Schantz notched the bridge on his earliest surviving piano, of about 1790, but then turned to the traditional bridge pinning with unequal string lengths, only returning to the notched bridge in about 1820.[229]

The English influence and the divided bridge

Only the two earliest surviving grand pianos by John Broadwood, both built in 1787, have single bridges.[230] All the remaining instruments by the Broadwood firm built after that date have divided bridges.[231] Of the Viennese makers, only Schantz, Streicher and Fritz appear to have used the divided bridge before 1820.

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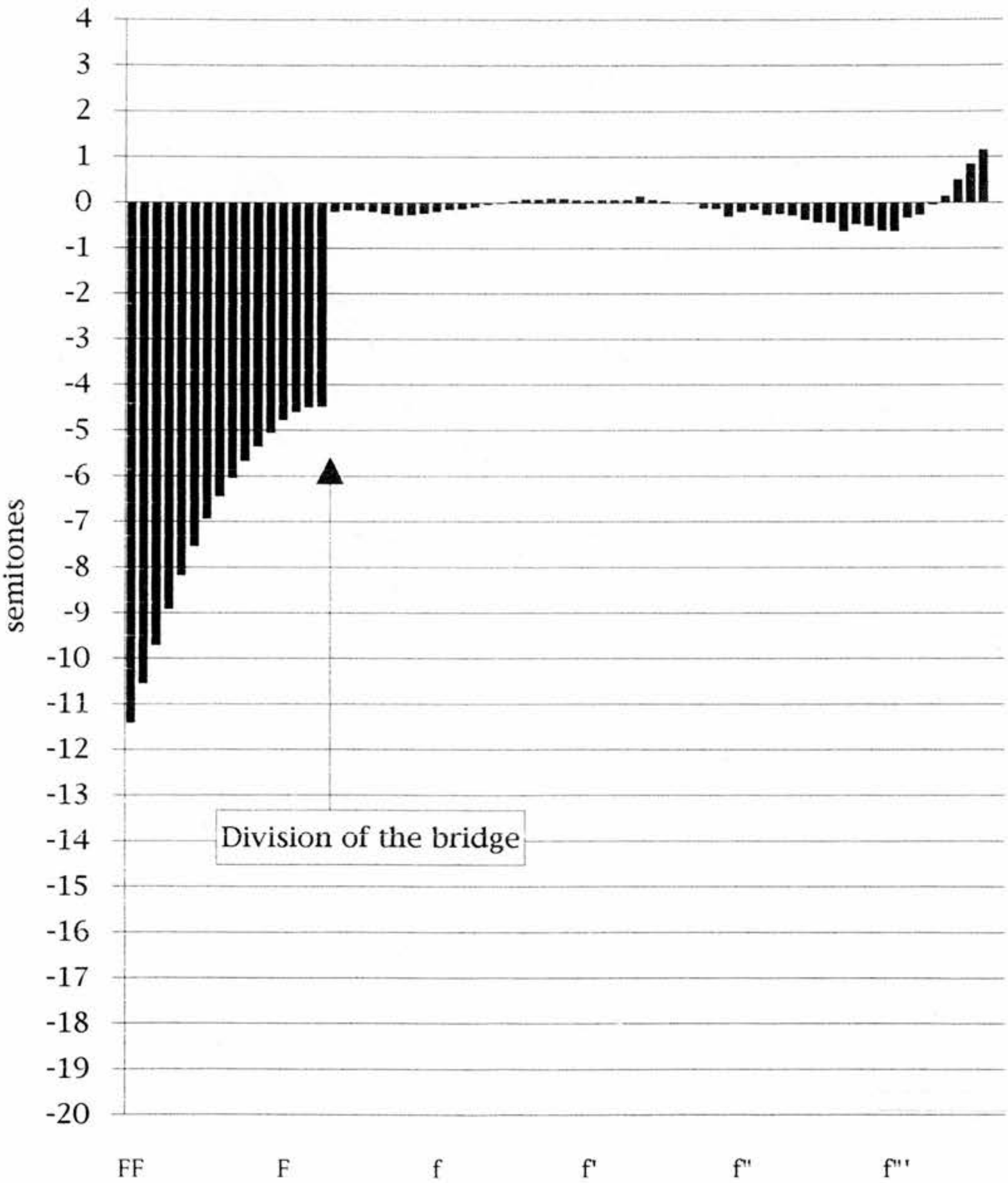
228 Broadwood's earliest grand piano (No. 69 in private ownership in England) has a notched bridge. All the pianos by Walter of c.1815 and later have equalised string lengths as do all pianos by Streicher from S/1807/733 onwards. The grand piano by Americus Backers of 1772 in the Russell Collection, University of Edinburgh, Cat. No. 24 has a notched bridge and equalised string lengths throughout.

229 Sz/2 (c.1790), Sz/12 (1821) and from Sz/15 (c.1820) have notched bridges.

230 No. 69 is in private ownership in England, No. 203 is in the Colt Collection, Bethersden, England, Inv. Nr. G279B.

231 The origins of the divided bridge in England are extensively dealt with in an article by John Koster, 'The Divided Bridge, Due Tension, and Rational Striking Point in Early English Grand Pianos', *Journal of the American Musical Instrument Society*, XXIII, 1997, 5-55.

Grand piano John Broadwood and Son 1796
(No. 946)
Deviation of the string Lengths
from a Pythagorean scale based on the length of
c"
expressed in semitones



graph 57

An advantage of the divided bridge for the scaling is that the geometric progression of the lengths of the iron strings can be continued further down in the bass without foreshortening. This is the case in Broadwood's early grand pianos. The scaling of the lowest iron strings is accurately Pythagorean (graph 57).

Schantz and the divided bridge

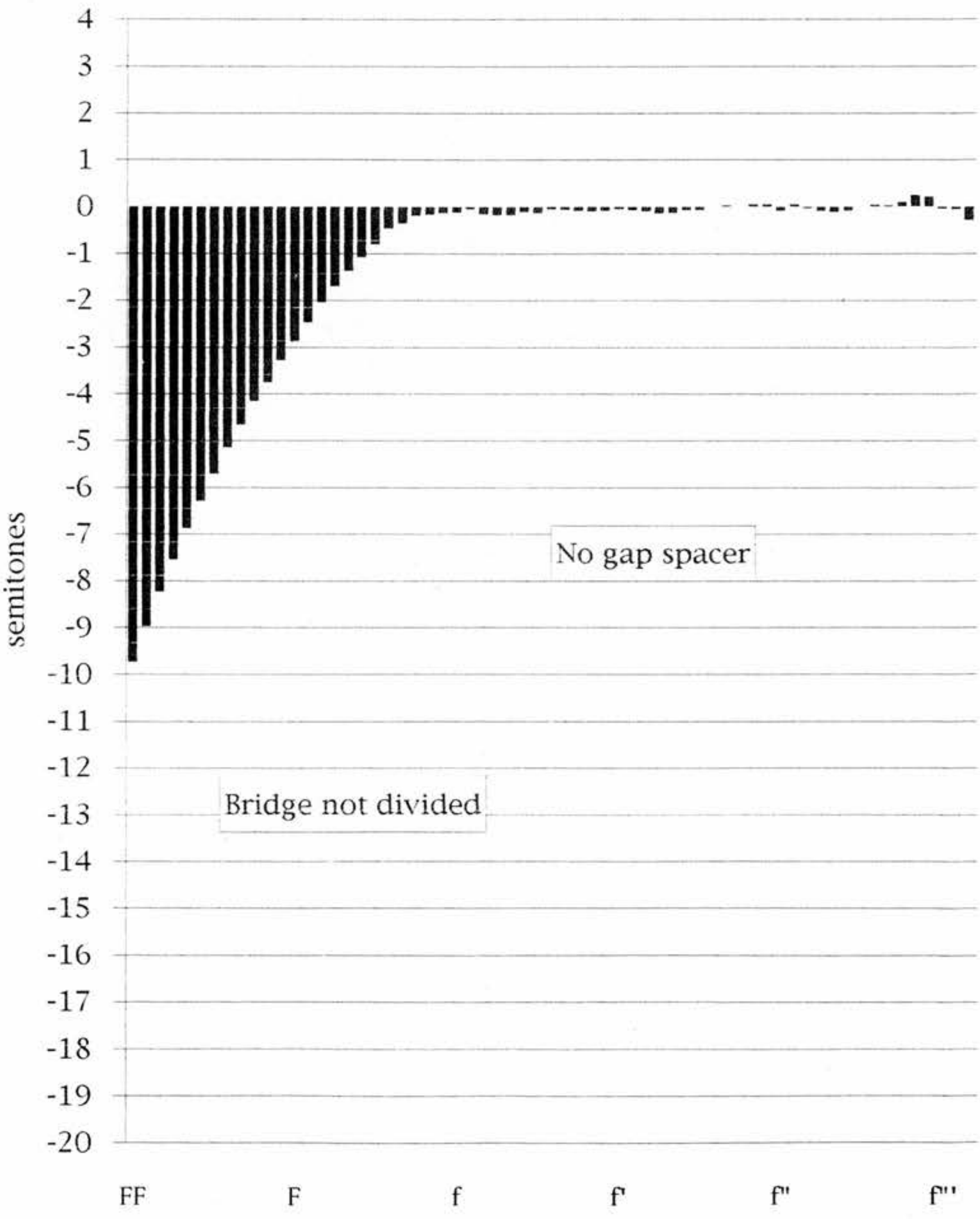
The second oldest surviving grand piano by Schantz, of about 1795, appears to be the oldest Viennese piano with a divided bridge. Schantz continued to divide the bridge until about 1815 when he reverted to a single bridge. In about 1820 he returned to a divided bridge. Between 1795 and 1815 the bridge is divided at G/G#, whereas after 1820 the divide is at F/F#, the traditional position for the change from brass to iron strings in Viennese pianos.[232]

In the oldest surviving grand piano by Schantz, which has a single bridge, appreciable foreshortening begins at the note d, reaches three semitones at G# and increases to about $9^1/_2$ semitones at FF (graph 58). In his pianos with the bridge divided at G/G# the lowest iron strings are not significantly foreshortened but the brass strings are as foreshortened as in the instruments

232 Walter is the most notable exception to the general rule that until about 1815 the Viennese makers changed from brass to iron at F/F#. Pianos by Schantz with the bridge divided at G/G# are Sz/3, Sz/4, Sz/4a, Sz/5, Sz/6 and Sz/7. Those with the divide at F/F# are Sz/16, Sz/16a, Sz/17, Sz/18, Sz/19 and Sz/20. The English and French instruments of the late eighteenth and early nineteenth century, including those of Erard and Broadwood, have bridges divided at G# /A.

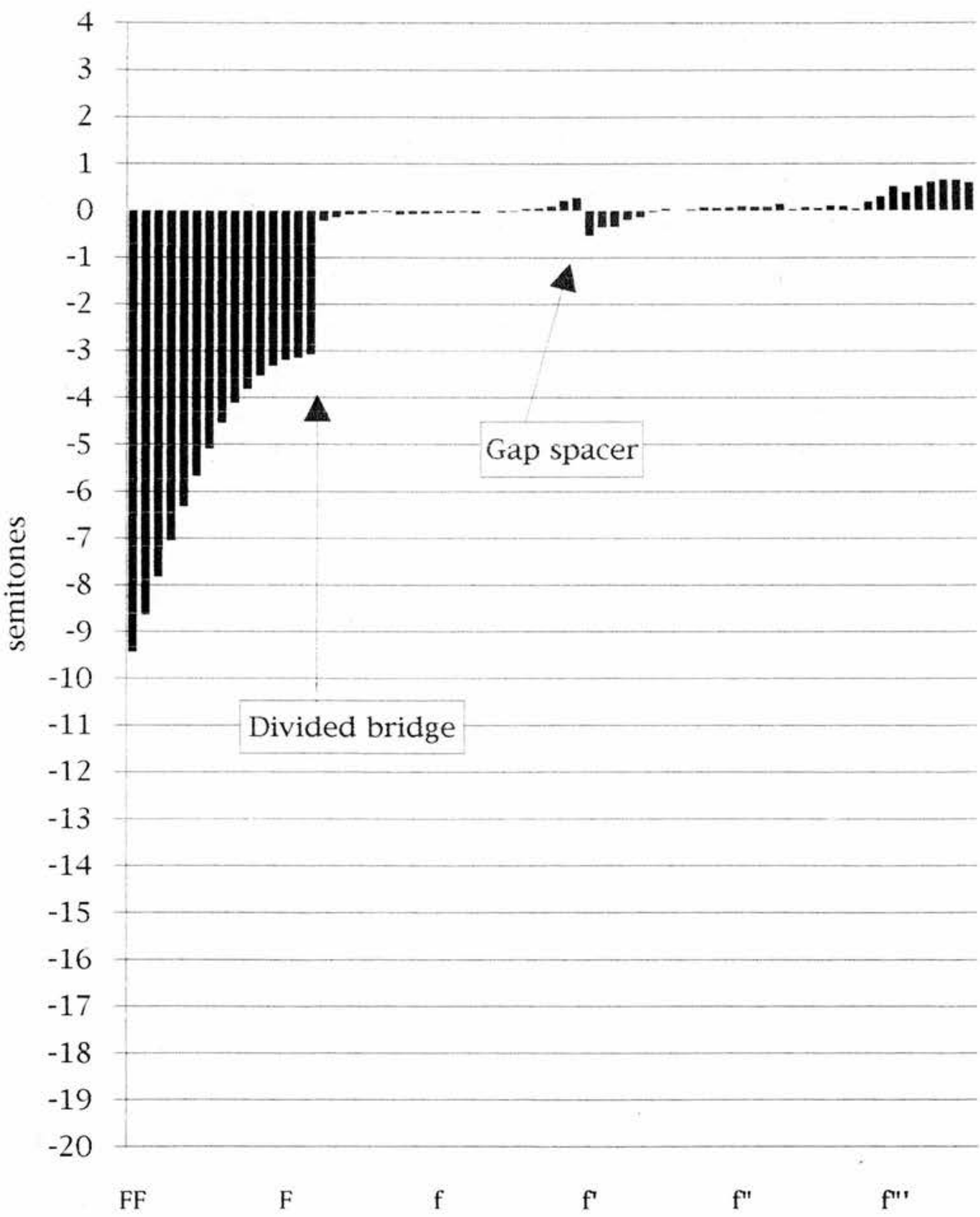
without a divided bridge (graph 59). Quantitatively, the divided bridge is to the advantage of the scaling in that the number of foreshortened choirs is reduced by seven. Qualitatively, the divided bridge eliminates the foreshortening of the iron strings.

Grand Piano Johann Schantz (Sz/2) c.1790
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 58

Grand Piano Johann Schantz (Sz/6) c.1795
Deviation of the string lengths
from a curve based on the length of c" and an
octave ratio of 1 : 1.95
expressed in semitones



graph 59

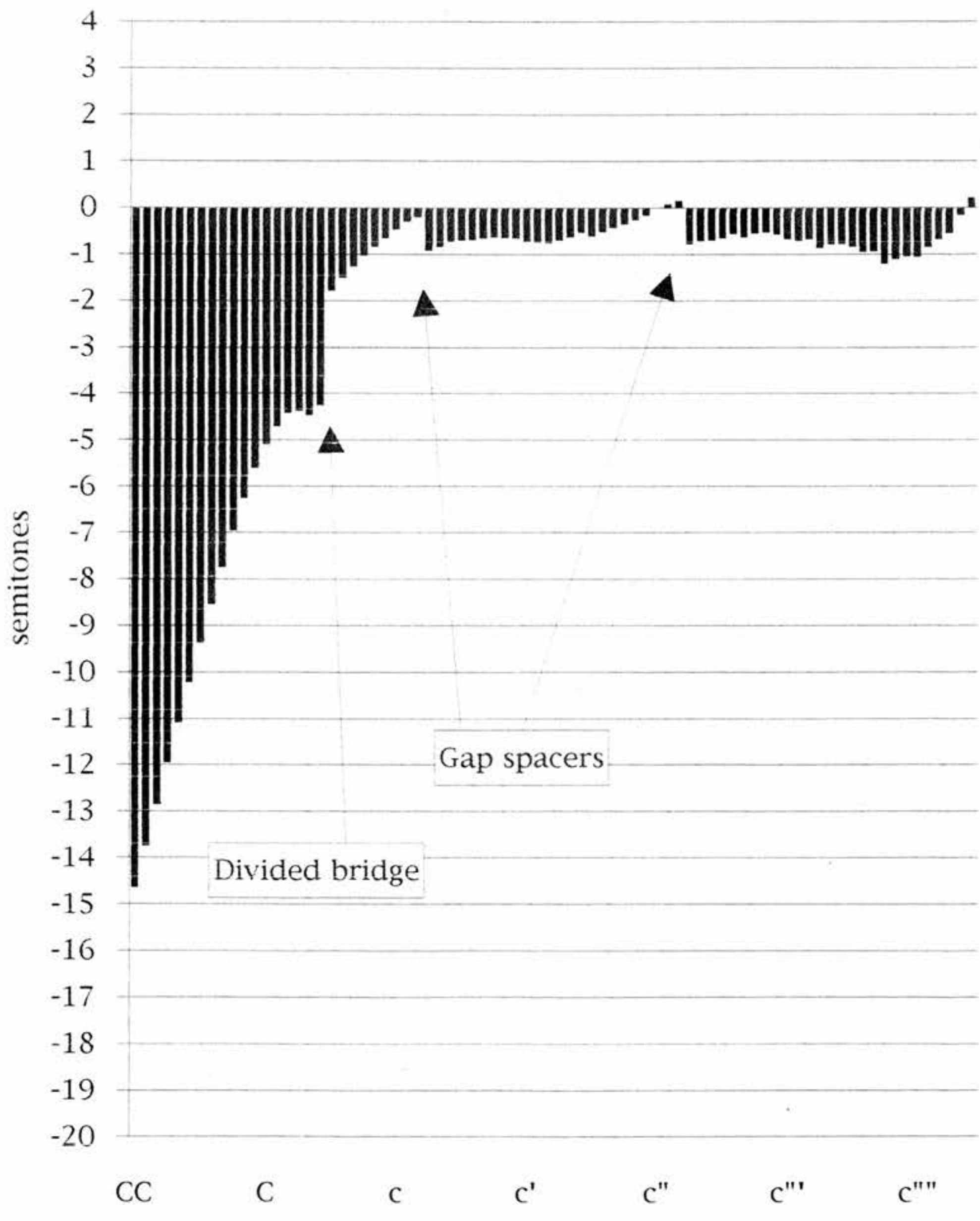
Streicher and the divided bridge

The earliest piano made by Nannette Streicher with a divided bridge is dated 1807, while the next surviving piano, built less than a year later, has a single bridge (graphs 60 and 61). The two pianos of 1811 and 1813 again have divided bridges but the pianos built between 1814 and 1820 have single bridges. The definite decision to use the divided bridge appears to have been taken in 1823 (graph 62).

All those pianos with a divided bridge made by the Streicher firm before 1835 have the divide at F/F#, even though from 1816 to 1820 those pianos without a divided bridge change from brass to iron at D/D# rather than at F/F#. Later, from 1839 at the latest, bridge was divided at C#/D.

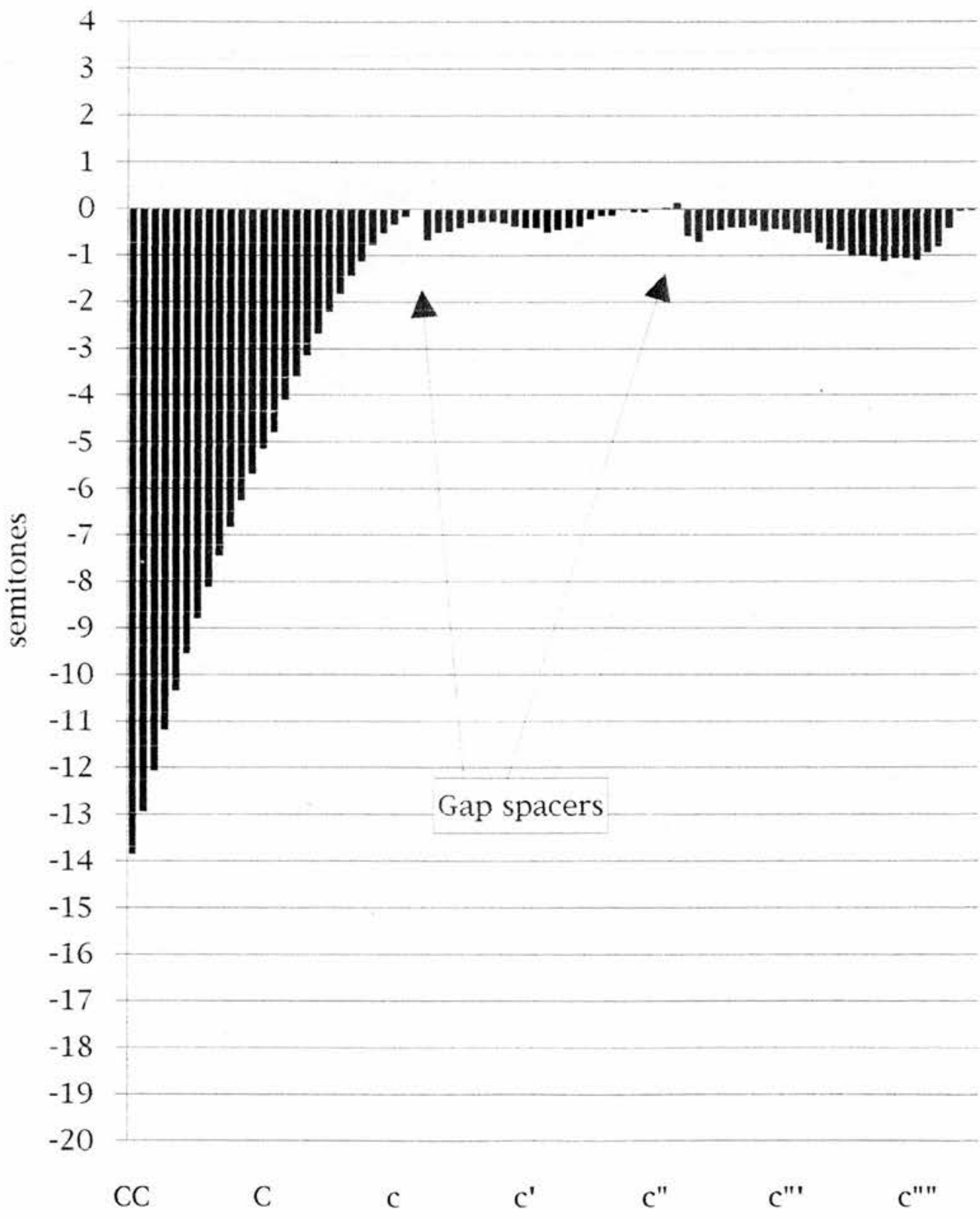
A comparison of the scaling pattern of the 1807 piano, which has a divided bridge, with that of the 1808 piano, which has a single bridge, shows that the divided bridge in the 1807 piano makes little difference to the scaling pattern (graphs 60 and 61). In the 1807 piano the string for the lowest note on the bridge for the iron strings, F#, is foreshortened by two semitones while the string for the same note in the 1808 piano is foreshortened only a fraction of a semitone more. In both pianos the strings for the note C are foreshortened by five semitones. The divided bridge thus makes little difference to the scaling; full advantage of the divided bridge was not taken to optimalise Pythagorean scaling in the 1807 piano. But in the 1823 piano the advantage of the divided bridge for the iron scaling is maximised (graph 62).

Grand Piano Nannette Streicher S/1807/733
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



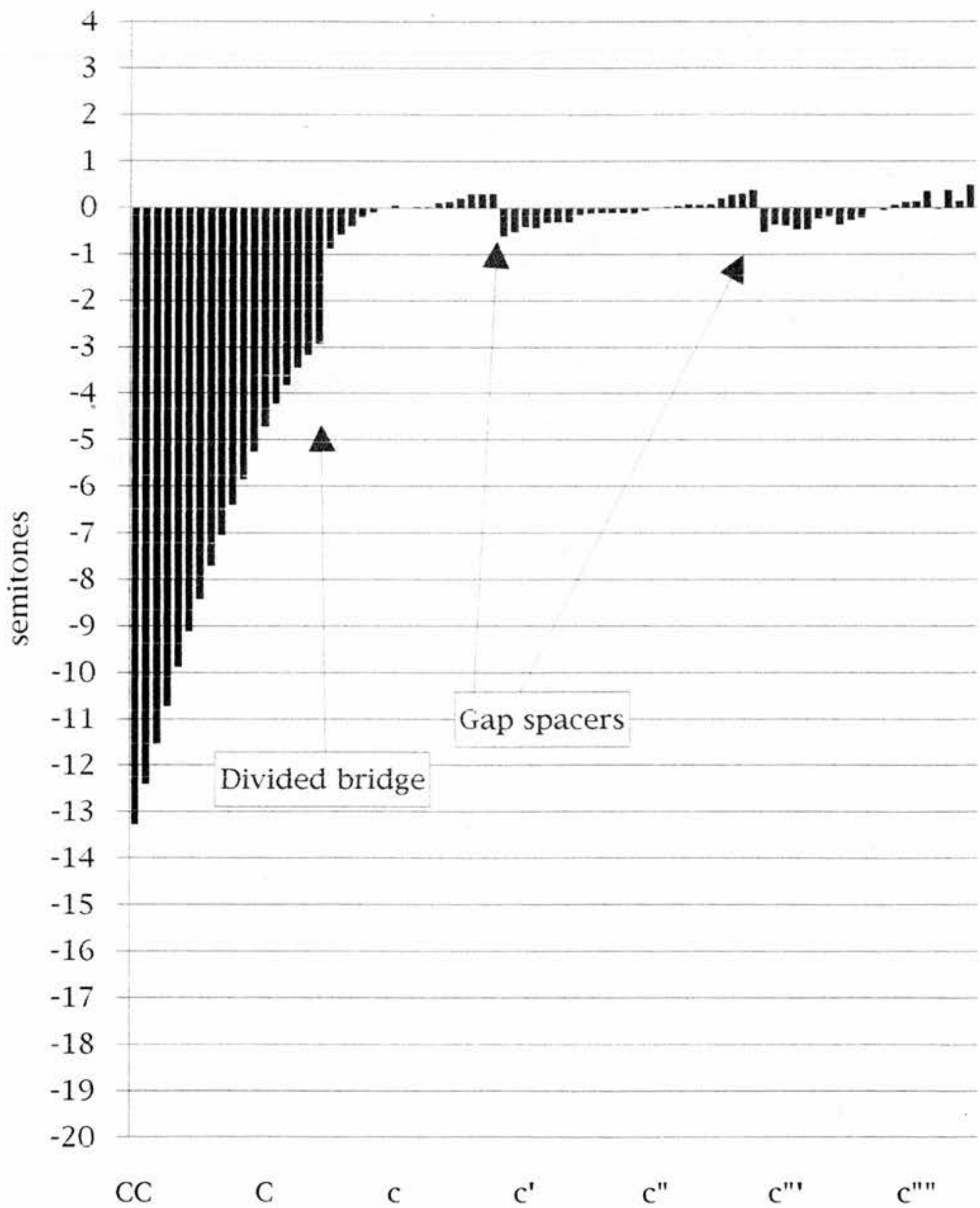
graph 60

Grand Piano Nannette Streicher S/1808/764
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 61

Grand Piano Nannette Streicher S/1823/1756
Deviation of the string lengths
from a Pythagorean scale based on the length of
c''
expressed in semitones



graph 62

Fritz and the divided bridge

Johann Fritz was also ambivalent towards the divided bridge. His two earliest surviving pianos, of c.1810 (F/1 and F/2), have their bridges divided at F#/G while those of between about 1815 and 1820 have single bridges. Not all of the latter pianos have repeated gauge markings indicating the position of the changeover from brass to iron. Those which do parallel the pianos of Streicher of the same period: the pianos of about 1815 have the changeover at F/F# (F/3 and F/3a) and those of about 1820 have the changeover at D/D# (F/4 and F/5) or D#/E (F/7). In about 1825, later than Schantz and Streicher, Fritz returned to the divided bridge.[233] Unlike Schantz, however, who started with the divide at G/G# and later turned to the more traditional Viennese position for the changeover from brass to iron, F/F#, Fritz started with the divide in the bridge at F/F# and later turned to G/G# (F/8).

The English influence in Vienna - summary

Of the important makers of the first two decades of the nineteenth century only Schantz, Streicher and Fritz divided the bridge. All three started with a single bridge, changed to the divided bridge, changed back to the single bridge and finally returned to the

233 The nut of F/8 is also divided. Broadwood used the divided the nut in 1791.

divided bridge in the 1820's. By that time the divided bridge had become standard in Vienna. The same ambivalence is apparent in the early use of the other English design features, the triple stringing, the English-style gap spacer and the equalisation of the string lengths for each choir.

Schantz was clearly influenced by the English and French traditions early on. We might even speculate that it was the piano given to Haydn by Erard in 1801 which served as a model for Schantz. Streicher was probably influenced by that piano and also by the piano which Erard gave to Beethoven. But both Beethoven himself and Härtel, the Leipzig publisher, who did a good business selling pianos of the Streicher firm, encouraged Streicher at least to investigate if not to emanate the English and French makers. It appears to have been the volume of the English and French instruments which impressed.

The positioning of the bridge, the bridge pins and the nut pins

Both Stein and Hofmann used standard lengths for the strings of the lowest note, FF. But the scaling design in the treble was continually shortened. Walter and Streicher appear to have changed their overall design more frequently. There are only pairs or small groups of pianos with the same lengths for the strings of the lowest note, making it more difficult to generalise about their instruments. Nonetheless it seems safe to presume that in general the bass end of the bridge was the fixed starting point for establishing the position of the bridge. The curve of the upper half of the bridge was most likely established according to a geometric progression based on one string length, probably the length of an f or c string.

Having determined the line of the bridge in this or some other way, the actual positions of the bridge pins and nut pins must have been established according to pre-determined distances in a line perpendicular to the spine which ensured that each choir of strings lay correctly above the appropriate hammer. The line-up of the strings above the hammers is more important than an exact adherence to a geometric progression. This is probably the main reason for some of the minor variations in the scalings of groups of instruments which otherwise appear to be built to the same scaling design. This is illustrated in table 61 which shows the scalings of three pianos by Hofmann. There can be little doubt that these three were made to the same design yet there is considerable variation in the treble scaling.

The scalings of three pianos by Hofmann

	H/c.1795a	H/c.1795b	H/c.1795c	Average	
	mm	mm	mm	mm	*Zoll* (Viennese inch)
FF	1632	1628	1639	1633	62.0
C	1462	1462	1467	1464	55.6
F	1283	1281	1289	1284	48.8
c	1022	1024	1026	1024	38.9
f	840	845	842	842	32.0
c'	574	578	582	578	22.0
f'	431	437	439	436	16.6
c''	284	287	287	286	10.9
f''	212	215	218	215	8.2
c'''	146	146	152	148	5.6
f'''	113	111	121	115	4.4

Table 61

The strings of the top octave of H/c.1795c are more stretched than in the other two pianos, probably simply the result of the practicalities of bending the bridge to glue it to the soundboard.

In the pianos of Stein, Hofmann, Streicher, Walter and almost all other makers the distance of the lowest nut pin from the spine is determined by the position of the lowest hammer, but the lowest bridge pin is further from the spine. The spine liner in the bass is also chamfered and sometimes the extreme bass end of the bridge is not glued to the soundboard; the underside of the bridge is cut away leaving a space under the bridge. In these ways the bass end of the bridge is given more free soundboard. Usually, the strings are parallel to the spine by at least the middle of the compass, although in some of Hofmann's pianos the process is reversed towards the treble so that the distance of the top bridge pin from the cheek is greater than the distance of the top nut pin from the cheek.

Two pianos by Nannette Streicher illustrate the principle that the actual lengths of the strings would have certainly been guided by a preconceived scaling plan but that in practice they were subordinated to the layout of the strings in relation to the hammers. These two pianos by Streicher, both undated, were made in about 1804. Both have the range FF to c"". One, veneered in yew, is in the Germanisches Nationalmuseum (S/c.1804a) and the other, veneered in cherry, is in the Musikinstrumenten-Museum of the University of Leipzig (S/c.1804b). Except in the tenor, the scalings of the two instruments are very similar although the string lengths of the Leipzig piano are between 2mm and 4mm longer than those of the Nuremberg piano (table 62). These small differences are accounted for by slight differences in the distances of the nut pins from the front edge of the wrestplank. In the Leipzig piano these are slightly shorter (by 1mm to 4mm) than in the Nuremberg piano (table 63). It is clear that the two instruments were built to the same scaling design. Yet for one area, centered on c, the string lengths of the Leipzig piano are appreciably longer, up to 13mm, than those of the Nuremberg instrument. But the positions of the bridge pins and the nut pins relative to the spine are virtually the same (table 63).[234] It is the accuracy of these distances which guarantee the positions of the strings in relation to the hammers and which therefore must take precedence over the precision with which the string lengths adhere to any preconceived scaling plan. The curves of the bridges of the two instruments are the same except in the area around c, where the incline of the bridge is at its steepest. Here, more so than in the three Hofmann pianos in table 61, a slight difference in the position of the bridge resulted in different tenor string lengths.

234 To within 1 or 2mm except the top and bottom note which are the same to within 3mm. It should be noted that the measurements of the coordinates of the bridge and nut pins are accurate to within 1mm either side.

The scalings of two pianos by Streicher (mm)

	S/c.1804a	S/c.1804b		S/c.1804a	S/c.1804b
FF	1678	1680	f'	420	424
FF#	1662	1664	f#'	395	400
GG	1643	1646	g'	374	378
GG#	1623	1628	g#'	352	355
AA	1605	1608	a'	332	336
AA#	1582	1584	a#'	313	316
BB	1555	1558	b'	295	298
C	1529	1530	c''	278	281
D#	1410	1414	c#''	262	265
E	1370	1375	d''	246	250
F	1331	1338	d#''	232	235
F#	1288	1296	e''	219	222
G	1247	1258	f''	206	208
G#	1203	1211	f#''	194	197
A	1161	1172	g''	183	186
A#	1120	1129	g#''	172	175
B	1079	1089	a''	162	165
c	1038	1048	a#''	154	157
c#	997	1010	b''	145	148
d	959	969	c'''	136	140
d#	923	932	c#'''	129	133
e	881	890	d'''	122	126
f	841	851	d#'''	116	119
f#	804	813	e'''	110	114
g	766	775	f'''	105	108
g#	730	738	f#'''	99	103
a	693	700	g'''	95	98
a#	655	663	g#'''	90	93
b	620	626	a'''	86	89
gap	590	597	a#'''	82	84
c'	559	564	h'''	78	80
c'#	528	533	c''''	74	76
d'	502	506			
d'#	474	476			
e'	446	448			

Table 62

Two pianos by Streicher: distances of the nut pins from the front of the wrestplank and of the nut pins and bridge pins from the spine (all mm)

	Nut pins from front of wrestplank		Nut pins from spine		Bridge pins from spine	
	S/1804a	S/1804b	S/1804a	S/1804b	S/1804a	S/1804b
FF	71	70	59	56	76	75
C	89	86	150	149	153	153
F	102	99	216	214	213	213
c	119	115	307	306	305	304
f	131	128	371	371	370	369
c'	147	144	474	473	475	475
f'	157	153	539	537	540	539
c''	169	166	629	628	631	631
f''	175	171	695	694	696	695
c'''	181	177	786	784	787	786
f'''	183	180	849	848	850	848
c''''	187	184	940	937	941	937

Table 63

Positions of the nut and bridge pins in relation to the spine
in the Eisenstadt
and the Mozart piano
(W/c.1782a & W/c.1782b)
(mm)

	Nut Eisenstadt	Nut Mozart	Bridge Eisenstadt	Bridge Mozart	String lengths Eisenstadt	String lengths Mozart
FF	59	61	96	93	1775	1771
C	158	160	188	184	1627	1629
F	226	229	253	250	1416	1442
c	319	321	338	336	1072	1075
f	388	389	402	400	815	818
c'	481	483	491	491	565	550
f'	552	552	557	558	432	419
c''	645	643	652	651	303	296
f''	703	703	719	721	224	221
c'''	805	806	814	812	150	149
f'''	875	874	883	882	119	124

Table 64

Two other instruments which have bridge pins and nut pins at the same distances from the spine are the one attributed to Walter, once owned by Mozart, W/c.1782b, and another by Walter, in Eisenstadt, W/c.1782a. The almost identical positions of both the nut pins and the bridge pins of these two pianos provide convincing evidence that they were made by the same maker (table 64).

Scaling design: summary

In general it seems that practical considerations were of prime importance to Stein, Hofmann and to Streicher when positioning the strings in their pianos. These practical considerations included the use of standard lengths for the FF strings, the use of simple ratios for determining string lengths, keeping the bridge on a free part of the soundboard and the accurate positioning of the strings above the hammers. These practical considerations took precedence over theoretical ones such as the precision with which string lengths conformed to a geometric progression, especially at the gap spacer, and the consistency with which the scaling was stretched in the treble. This practical attitude was largely shared by Schantz. Besides this, however, Schantz was probably the first in Vienna to experiment with particular aspects of scaling design which were derived from theoretical considerations. These included the equalization of the lengths of the strings of each choir and the use of the divided bridge.

Walter, with his careful positioning of the gap spacer and the string choirs on either side of it, and a well thought-out and consistent treble design, may have been more keenly aware of theoretical considerations and the practical consequences for the sound of an uneven scaling. He may, for instance, have thought of the avoidance of the discontinuity in the scaling around the gap spacer as important for the consistency of the sound of his pianos. In 1811, Bleyer certainly thought that there was a relationship between the sound of an instrument and its scaling. When discussing problems of stringing he stated that in general, the scalings of instruments had become

> 'so garbled through mechanical tradition and supposed improvements that no original octave relationship was to be found. The extent to which the evenness of the sound suffers from a garbled scaling and from stringing with gauges with no proportion is easy to understand. Of course, it is often replied to this that the evenness of the sound can be restored by skilful leathering. Probably, yes, but how long will this artificial evenness last?' [235]

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235 '*Diese war durch mechanische Tradition und vermeintliche Verbesserungen so sehr verstümmelt, dass kein ürsprungliches Octaven-Verhältnis zu entdecken war. Wie sehr die Gleichheit der Klänge unter einer verstümmelte Mensur und unter einer Besaitung, deren Nummern kein Proportion haben, leidet, ist leicht zu ersehen. Zwar wird mancher hierauf erwiederen, man könne durch geschickte Belederung die Gleichheit der Klänge herstellen. Wohl, ja, aber wie lange wird diese erzwungene Gleichheit dauern?*' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII,* Leipzig, November 1811, 75.

Scaling and the *Zoll*

Some studies of string lengths show that the design of the scaling of an instrument is often based on simple nominal lengths for the notes c or f when these are measured according to the unit of measurement used by the maker. An English instrument might turn out, for instance, to have a 'ten-inch scale', implying that the maker based the scaling of the instrument on a c" string length of 10 English inches, giving a c"' of 5 inches and a c' of 20 inches. This type of analysis, using the local unit of measurement, can reveal information about the design and even the origin of particular instruments.

When the string lengths of the two pianos by Streicher, S/c.1804a and S/c.1804b are converted from millimeters to Viennese inches or *Zoll*, the lengths of the f strings fall into a clear pattern based on a length of 16 *Zoll* for the note f' (table 65). FF is foreshortened by 12 semitones and thus has the length F would have if Pythagorean scaling were continued down to the bottom note.

The three surviving grand pianos by Kober also have scalings which were probably based on a 16 *Zoll* f' string length (table 66). The bass scaling follows the same pattern as the two pianos by Streicher with a 32 *Zoll* f string and a 64 *Zoll* FF string, thus achieving a foreshortening in the bass of 12 semitones. In the treble half of the compass, however, the scaling is tapered, using an octave ratio of about 1 : 1.95.

One might have assumed that these pianos by Kober had been designed according to a Pythagorean scaling. After all, a 16 *Zoll* f', a 32 Zoll f and a 64 *Zoll* FF point to a simple whole number approach based on the doubling of the string lengths for each drop of an octave. One might then further assume that the lengths for f'' (8.42 *Zoll*) and f''' (4.31 *Zoll*) were 'near enough' and assigned them 'nominal' lengths of 8 *Zoll* and 4 *Zoll* respectively. But such an analysis would not have revealed the subtlety of Kober's scaling design which, although based on Pythagorean principles, is modified according to an octave ratio of 1 : 1.95 in the treble half of the compass. That this scaling pattern was intentional and not fortuitous is shown by the precise correspondence between the string lengths of the three pianos.

Comparison of the string lengths of two similar pianos
by Streicher
in mm and in Viennese *Zoll*

	S/c.1804a			S/c.1804b	
	mm	*Zoll*	Nominal *Zoll*	mm	*Zoll*
FF	1678	63.8	64	1680	63.8
C	1528	58.1		1530	58.1
F	1331	50.6		1338	50.8
c	1038	39.4		1048	39.8
f	841	32.0	32	851	32.3
c'	559	21.2		564	21.4
f'	420	16.0	16	424	16.1
c''	278	10.6		281	10.7
f''	206	7.8	8	208	7.9
c'''	136	5.2		140	5.3
f'''	104	4.0	4	107	4.1
c''''	74	2.8		76	2.9

Table 65

Three grand pianos Ignatz Kober
The averaged measured string lengths in mm and Zoll compared with the theoretical lengths generated using an octave ratio of 1 : 2 from the average length of f'

	{Vienna 1}	{Braunau}	{Prague}	Average length		Nominal length	
Note				mm	*Zoll*	mm	*Zoll*
FF	1687	1681	1687	1685	64.02	3384	128.58
C	1543	1537	1540	1540	58.51	2259	85.82
F	1333	1326	1327	1328	58.48	1692	64.29
c	1036	1028	1025	1030	39.12	1129	42.91
f	823	816	820	820	31.14	846	32.14
c'	555	550	557	554	21.05	564	21.45
f'	424	422	424	423	16.07	423	16.07
c''	295	291	291	292	11.11	282	10.73
f''	223	221	221	221	8.42	212	8.04
c'''	149	148	151	150	5.67	141	5.36
f'''	112	113	115	113	4.31	106	4.02

Table 66

Four pianos by Hofmann
String lengths in mm and in Viennese *Zoll*

		FF	C	F	c	f	c'	f'	c"	f"	c"'	f"'	c""	f""
H/c.1785c	mm	1633	1467	1293	1036	858	599	449	293	219	144	108		
	Zoll	62.0	55.7	49.1	39.4	32.6	22.8	17.1	11.1	8.3	5.5	4.1		
H/c.1795a	mm	1632	1462	1283	1022	840	574	431	284	212	146	113		
	Zoll	62.0	55.6	48.7	38.8	31.9	21.8	16.4	10.8	8.1	5.5	4.3		
H/c.1805	mm	1631	1441	1251	985	789	558	417	277	208	143	110	79	
	Zoll	62.0	54.8	47.5	37.4	30.0	21.2	15.8	10.5	7.9	5.4	4.2	3.0	
H/c.1820	mm	1750	1542	1340	1030	807	537	414	270	203	137	103	67	50
	Zoll	66.5	58.6	50.9	39.1	30.7	20.4	15.7	10.3	7.7	5.2	3.9	2.5	1.9

Table 67

The assumption that piano makers based their scaling designs on whole numbers and simple fractions of the local inch for the lengths of the strings of either the c's or the f's obscures not only the subtleties of using octave ratios other than 1 : 2 but also the gradual change in absolute string lengths from one instrument to the next. In the pianos of Hofmann the length of the string of the lowest note, FF, remains the same for all but the two six-octave pianos. But from about F upwards, the later the piano, the shorter the strings. The lengths of the c and f strings of four pianos by Hofmann are given in table 67 both in millimeters and Viennese *Zoll*:

The lengths of the strings expressed in Viennese *Zoll* give no clear indication that Hofmann used either the length of an f string or a c string as the basis for the design of his instruments. Both are possible, with an 11 *Zoll* length for c" in H/c.1785c or a 16 *Zoll* length for f' in H/c.1805. Although the latter is more likely (both Streicher and Kober used a 16 *Zoll* length for f') neither is convincing. Little is gained by expressing the string lengths of Hofmann's pianos in *Zoll*; the fractional decreases in the string lengths from one instrument to the next do not become clearer or more easily understood.

The length of the c" string, often used to describe the scaling of a particular piano, takes no account of the use of octave ratios other than 1 : 2 or of bass foreshortening or treble stretching or of any irregularities caused by the gap spacer. But foreshortening appears to depend on case length rather than on scaling design and treble stretching appears to be a means of keeping the bridge on free soundboard in the extreme treble rather than being a direct part of the scaling design. The c" string length remains representative of that part of the scaling which follows a geometric progression (or more or less follows a geometric progression) and is therefore, within certain limits, a useful shorthand for comparing scalings.

Contemporary instruments by different makers often have different absolute scalings. Two pianos of 1796 by Könnicke, for instance, have c" string lengths of 290mm and 294mm while a c.1796 piano by the *Geschwister* Stein has a c" string length of 282mm.[236] Two pianos of about 1805 by Rosenberger have c" string lengths of 293mm and 292mm while a piano by Hofmann of about the same date has a c" string length of 277mm.[237]

The scalings of the instruments of different makers thus vary synchronically. The scalings of the instruments of each individual maker vary diachronically. In general, makers designed

236 K/3, 1796, c" 290mm; K/4, 1796, c" 294mm; (S/1784, 1784, c" 295mm). S/c.1796/27, c.1796, 282mm.

237 Rosenberger: {Milan} and {Italy}. I am grateful to Stefano Strufaldi for bringing {Italy} to my attention. Hofmann: H/c.1805.

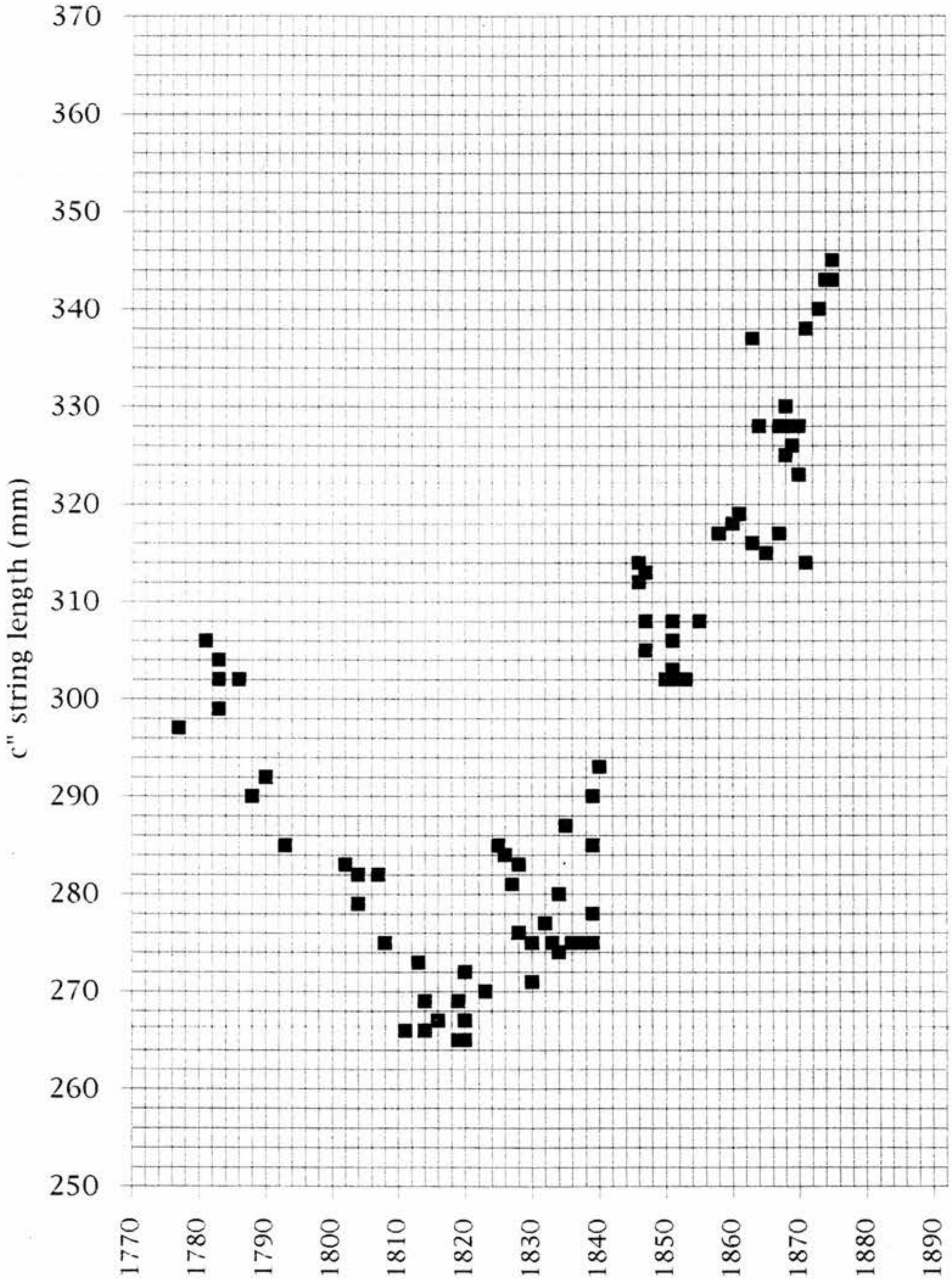
their pianos with continually shorter strings for the treble half of the compass until about 1820: the later the piano the shorter the strings of that part of the scaling which follows a geometric progression. In the early 1780's, Stein, Hofmann and Walter used a c" string length of about 300mm but by 1820, their firms were using c" string lengths of around 270mm.

The lengths of the c" strings of a large number of pianos by Stein and the Streicher firm are shown in graph 63. Tables 68 and 69 give the c" string lengths of a number of grand pianos by Hofmann and Walter.[238]

Three possible reasons for why pianos were designed for continually shorter strings between the early 1780's and 1820 present themselves. First, the total tension on the wooden case structure, considerably increased by the use of thicker strings, is reduced by shortening the scaling. Second, due to the effect of tensile pick-up, by which thicker strings are relatively weaker compared to thinner strings, shortening the increasingly thicker strings used reduces the danger of strings breaking. Third, any rise in pitch between 1780 and 1820 would have brought the strings closer to breaking point. Shortening the strings again reduces the risk of strings breaking. The main reason for shortening the strings was undoubtedly the lower tensile strength of the thicker strings.

238 Instruments with unreliable string lengths, for instance those with new soundboards, have been ommitted. Those pianos probably intended for a higher pitch standard have also not been included. The square pianos of the period generally do not follow the same pattern with respect to scaling as the grand pianos considered here.

Pianos of the Stein and Streicher firm
The variation in the length of the c" string over time



graph 63

Pianos by Walter
c" string lengths c.1782-c.1820
(mm)

W/c.1782a	303
W/c.1782b	296
W/c.1785a	297
W/c.1785c	283
W/1796	287
W/c.1800a	282
W/c.1800b	282
W/c.1800e	284
W/c.1805a	289
W/c.1805b	282
W/c.1815d	285
W/c.1815e	285
W/c.1815f	285
W/c.1817	285
W/c.1820	270*

Table 68

* Not measured by the author

Pianos by Hofmann
c" string lengths c.1785-c.1820
(mm)

H/c.1784a	309
H/c.1784b	306
H/c.1785a	298
H/c.1785b	300
H/c.1785c	293
H/c.1785d	288
H/c.1790b	289
H/c.1795a	284
H/c.1795b	287
H/c.1795c	287
H/c.1795f	287
H/c.1800	283
H/c.1805	276
H/c.1820	270

Table 69

CHAPTER VI

STRING TENSION

All string tensions in this and the following chapter have been calculated using the formula

$$T = \rho\pi/g \;.\; d^2f^2l^2$$

where T is string tension in kilograms, ρ is string material density, d is string diameter in meters, f is frequency in Hz, l is the string length in meters and g is the acceleration of gravity = 9.81 m/sec^2.[239]

Around 1800 there was little or no exact standardisation in the absolute diameters to which the nominal wire gauges referred; wire sold as one particular gauge could vary in diameter. In general the diameter to which each gauge number referred appears to have become thicker as time went on. To enable comparison, some more or less arbitrary gauge diameter standards have been set here. All those instruments dated before 1820 are assumed to have been strung with wire of diameters conforming to the gauge equivalents given by Thomée in 1866 for the Nuremberg system.[240] Those instruments dated 1820 to 1835 are assumed to

239 Properly speaking the unit of weight or kgf (kilograms force) should be used rather than the unit of mass, kg (kilograms).

240 See H. Thomée, 'Untersuchungen über Draht- und Blechlehren',

have been strung with wire diameters conforming to Huber's 'Berlin' system.[241] Finally, the few instruments by the Streicher firm discussed here and built in 1835 or later are assumed to have been strung with the wire diameters defined by the Streicher gauge caliper, conforming to the set of diameters called by Huber the Vienna system.[242]

Another assumption made simply in order to enable comparison is a standard pitch of a' = 430Hz. The pitches of all other notes have been calculated according to equal temperament. While comparison would not be possible without these assumptions they also limit the validity of any generalisations about tension made here.

Total tension and case structure

The trend to shorten the scaling is linked to the trend to increase string diameters. The total string tension forms one aspect of this relation because an increase in string thickness brings with it an increase in the total string tension. This increase, which must be

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Zeitschrift des Vereines Deutscher Ingineure, X, 1866, 659-60. For the mm equivalents see table 8 above.

241 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 217. For the mm equivalents see table 19 above.

242 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 204. For the mm equivalents see table 23 above.

carried by the case structure, is reduced by shortening the thicker strings. Bleyer pointed to the problem of string tension and case distortion in 1811 when he wrote

> 'If one builds the case in the normal way, that is with solid case members, and no matter how much one braces the sides, one finds after half a year, if one takes out the soundboard, that all the braces are loose having become pressed into the case sides by a line [a little more than 2mm] because of the tension of the strings which is about 90 *Centner* [4500kg].'[243]

Graph 64 shows how the tension on the cases of the pianos of Hofmann only increased a little between about 1785 and 1805. There was a dramatic increase, however, with the last piano, H/c.1820. This instrument not only has a larger compass than the earlier instruments but is triple-strung throughout, both factors which contribute to the increase in total tension, more than double that of the earlier instruments.

H/c.1820 is the only piano by Hofmann with gauge markings which has a total tension around the 90 *Centner*, or 4500kg, mentioned by Bleyer in 1811. Like H/c.1820, H/c.1815 is triple-strung throughout the compass and would probably have

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243 '*Baut man einen Kasten auf die gewöhnliche Art, nämlich mit massieven Sargstücken und verstrebt die Wände noch so sehr, so findet man in einem halben Jahre, wenn man den Resonanzboden heraus reisst, dass sich durch die Spannung der Saiten, welche bey 90 Centner beträgt, alle Streben bey einer Linie tief in den Wänden eingedrükt haben, und nun ganz los sind.*' 'Historische Beschreibung der aufrechtstehenden Forte-Pianos, von der Erfindung Wachtl und Bleyers in Wien', *Intelligenz-Blatt zur allgemeinen musikalischen Zeitung, No. XVII*, Leipzig, November 1811, 75.

had a total tension similar to that of H/c.1820. The gauge markings, now missing, were most likely written on the front edge of the old soundboard. The latter has been replaced, perhaps in the first quarter of the nineteenth century, judging by the seemingly original strings.

The internal structures of all the grand pianos by Hofmann are very similar to each other; they all have a so-called A-frame construction in which the letter A is formed by the spine liner, the bentside liner, which runs in a straight line from the tail to the bellyrail, the bellyrail itself and the cheek liner. Each of these case members extend the full depth of the instrument from under the soundboard down to the baseboard to which they are glued.

The total tension of a number of pianos by Hofmann is compared with the thicknesses of the bottom, the wrestplank, the A-frame bentside member and the bellyrail in table 70. The dimensions of the load-bearing members are intended to give a measure of the strength of the case structure.

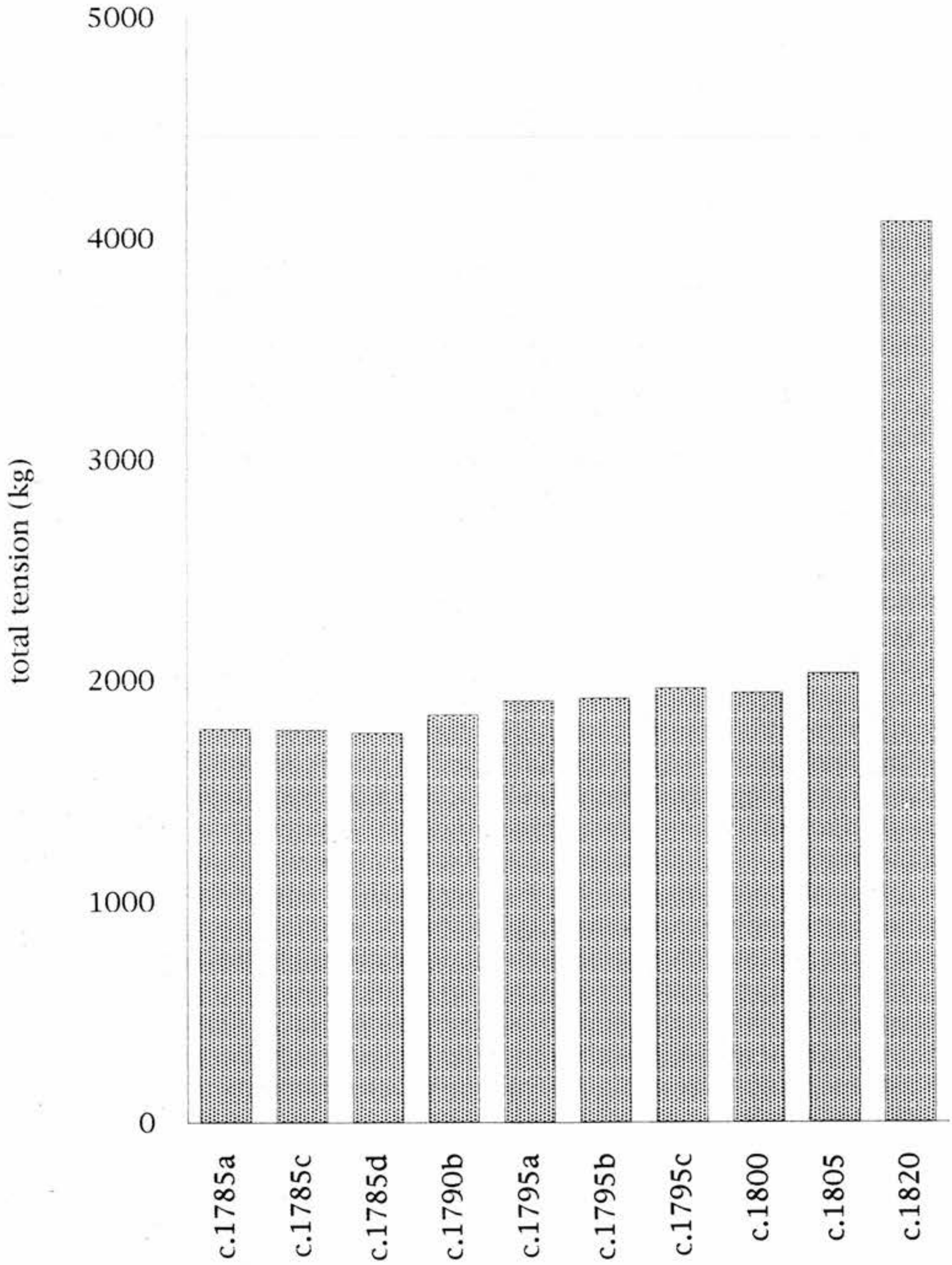
In the period between about 1785 and 1805 there was an increase in total tension from 1780kg to 2029kg, an increase of about 15%.[244] Despite this increase, Hofmann did not strengthen the structure of his instruments, keeping the dimensions of the most important case members the same. But in the new designs for the six-octave instruments, in which the total tension on the case was doubled, Hofmann considerably enlarged the cross-sections of

244 The seeming exactness of these total tensions belies the arbitrary nature of the assumptions.

the load-bearing members.

The total tension only increased by about 15% between about 1785 and 1805. It is interesting to calculate the extent to which an extra increase in total tension was avoided by using shorter strings during that period. The total tension on H/c.1805 using the actual string lengths as measured is 2029kg. If Hofmann had combined the thicker gauges marked on H/c.1805 with the longer scaling of H/c.1785c, the total tension would have been 2229kg, an increase of about 10%. The increase in tension was reduced from 25% to 15% by shortening the strings.

Comparison of the total tensions on
ten grand pianos by Ferdinand Hofmann
a' = 430Hz



graph 64

Some dimensions of load-bearing members of ten pianos by Hofmann compared with the total tension of the strings

	Bottom thickness mm	Wrestplank thickness x width mm	Bellyrail thickness mm	A-frame member thickness mm	Total tension kg
H/c.1785a	35	48 x 195	?	?	1780
H/c.1785c	40	49 x 195	69	41	1775
H/c.1785d	36	49 x 195	67	41	1761
H/c.1790b	34	47 x 195	66	42	1834
H/c.1795a	33	46 x 195	64	45	1894
H/c.1795c	34	49 x 196	67	47	1941
H/c.1800	31	47 x 197	67	45	1931
H/c.1805	35	49 x 197	64	44	2041
H/c.1815	38	49 x 226 (av.)*	85	64	?
H/c.1820	56	55 x 225 (av.)	106	91	4076

Table 70

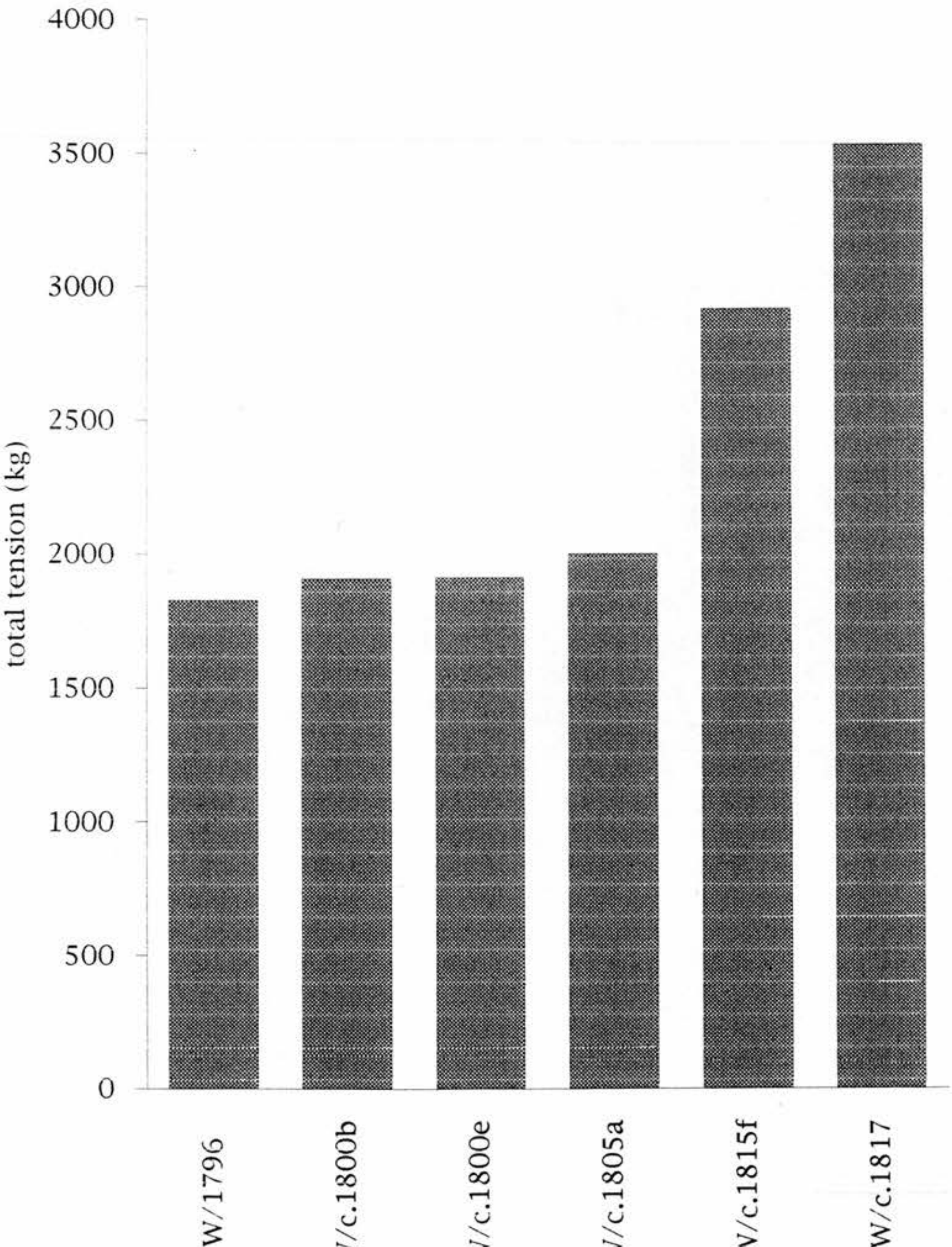
Note: The action of H/c.1785a cannot be taken out because of the distortion of the wrestplank so that the bellyrail and A-frame member thicknesses could not be measured.

* av. indicates that the width given is the average between the bass and treble widths.

In graph 65, the total tension on some instruments of Walter are compared. The total tension between 1796 (1851 kg) and c.1817 (3530kg) is almost doubled. Unlike Hofmann, Walter changed the type of internal structure of his pianos during this period so that a comparison of their case strengths cannot made on the basis of the dimensions of the load-bearing members. Nevertheless, a comparison of the thickness of the bellyrail, the thickness of the baseboard and the wrestplank cross-section, essential to the various case constructions utilised by Walter, gives some indication of the increase in the strength of the case structure (table 71). For those instruments with an A-frame construction the thickness of the bentside frame member is also given.

The pianos by Walter which have survived with complete sets of string gauge markings show that as the total tension increased Walter also increased the thicknesses of the load-bearing members but that he did so irregularly, by fits and starts.

Total tensions on six grand pianos made by the Walter firm
a' = 430Hz.



graph 65

Total tensions on a selection of pianos by Walter
compared to some dimensions of load-bearing members

	Total tension kg	Bellyrail thickness mm	Wrestplank thickness x width mm	Bottom + frame thicknesses mm	A-frame bentside member thickness mm
W/c.1782b	?	31	32 x 197 (av.)*	25 + 30	none
W/c.1796	1851	57	47 x 185 (av.)	21 + 19	none
W/c.1800b	1906	57	46 x 176 (av.)	25 + 20	none
W/c.1800e	1911	57	46 x 209 (av.)	23 + 17	57
W/c.1805a	1999	60	45 x 206 (av.)	32 + none	63
W/c.1815f	2914	75	46 x 205 (av.)	25 + none	70
W/c.1817	3530	66	54 x 233 (av.)	24 + none	75

Table 71

* Av. indicates that the width given is the average between the bass and treble widths.

A similarly erratic pattern is presented by the pianos of Stein and of the Streicher firm (table 72, graphs 66 and 67). Except for the three combination instruments by Stein, S/1777, S/1781 and S/1783c, all his pianos and those of Nannette Streicher are built with the so-called A-frame. The bentside A-frame member is one of the most important structural parts of the case and its thickness has also been included in graph 67.

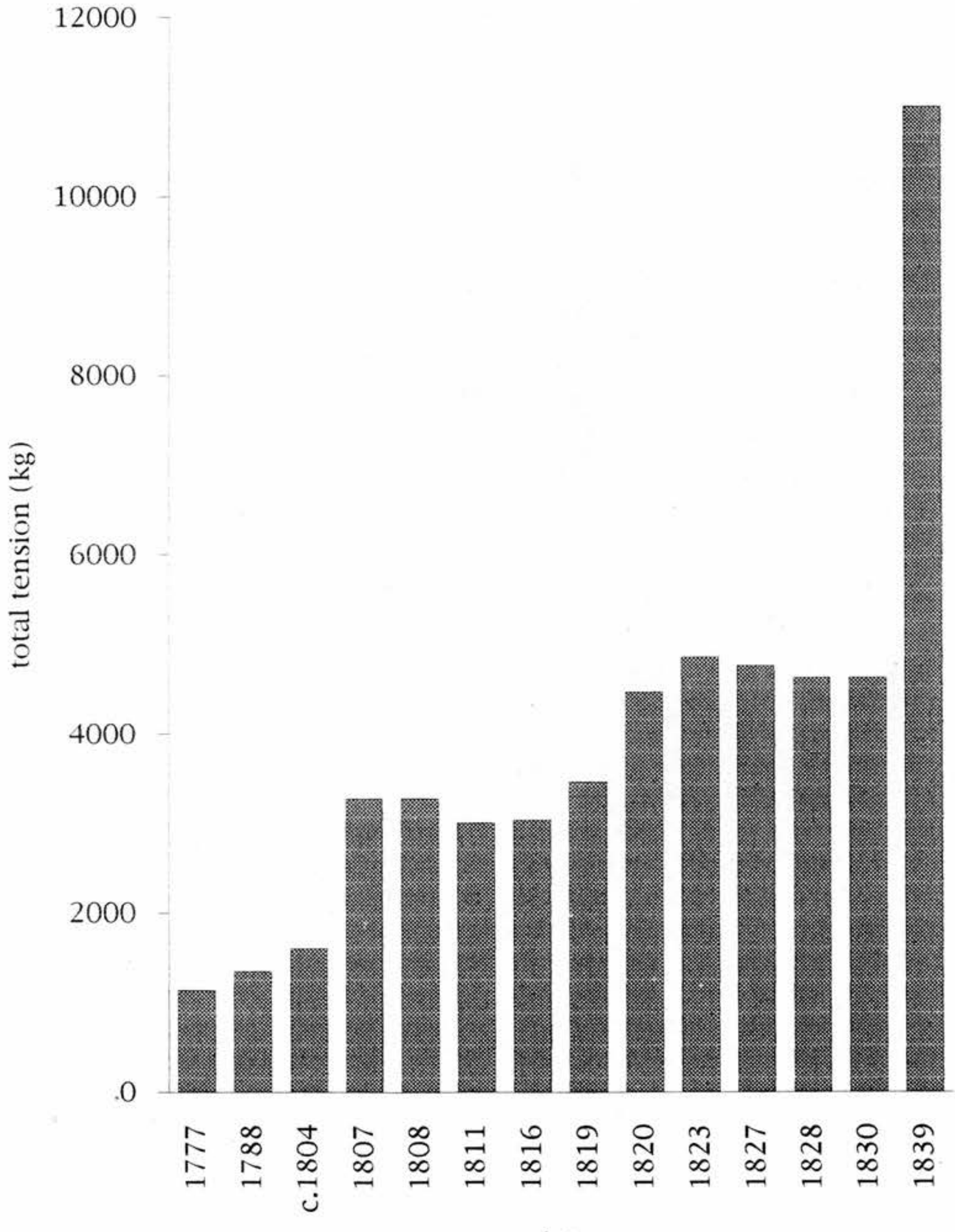
Total tensions on a selection of pianos by Stein and the Streicher firm compared to some dimensions of load-bearing members

	Total tension kg	Bellyrail thickness mm	A-frame member thickness mm	Wrestplank thickness x width mm x mm
S/1777	1142	25	none	31 x 205
S/1788a	1352	44	40	44 x 184
S/c.1804a	1607	48	32	50 x 186
S/1807/733	3278	60	46	54 x 196 (av.)*
S/1808/764	3277	78	52	54 x 194 (av.)
S/1811/902	3035	83	79	54 x 218 (av.)
S/1816/1117	3040	70	52	58 x 217 (av.)
S/1819/1415	3464	73	70	58 x 231 (av.)
S/1820/1550	4466	74	81	58 x 232 (av.)
S/1823/1756	4858	76	70	58 x 250 (av.)
S/1827/2185	4763	85	76	58 x 233 (av.)
S/1828/2237	4630	86	80	57 x 233 (av.)
S/1830/2383	4629	87	76	57 x 234 (av.)

Table 72

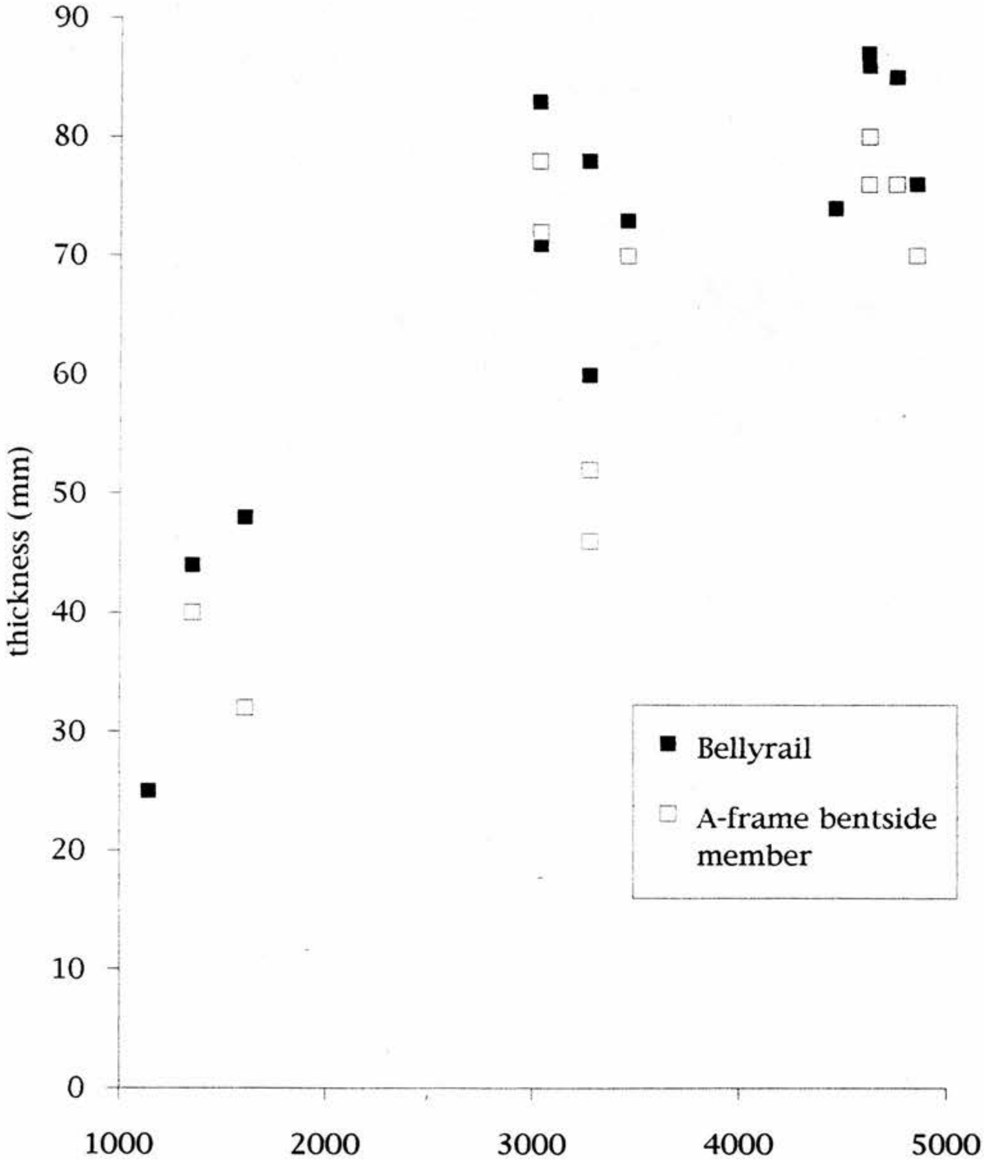
* av. indicates that the width given is the average between the bass and treble widths.

Total tensions on grand pianos made by
Stein and the Streicher firm
a' = 430Hz.



graph 66

Pianos by Stein and Streicher
The variation of the bellyrail and A-frame
bentside member thicknesses
with the total tension on the case
(a' = 430Hz)



graph 67

Total tension - conclusion

The rough correlation between the total string tension and the thicknesses of the load-bearing members in the pianos of Stein, Streicher, Hofmann and Walter suggests that the string diameters and the case structure were two more or less dependent design elements. But thicker strings and the resultant increase in stress on the case did not always go together with, for instance, a thicker wrestplank or bellyrail. It therefore seems unlikely that the primary reason for shortening the strings was to lower the total tension.

Tension distribution

In modern piano design equality of the string tension throughout the compass is considered to be advantageous. Samuel Wolfenden, for instance, states in his treatise on piano construction (1916):

> 'It is now known from experience that practical equality of tension throughout the instrument tends to prevent changes in tuning due to variations in the temperature. When the tension is equal the temperature movements are equal.'[245]

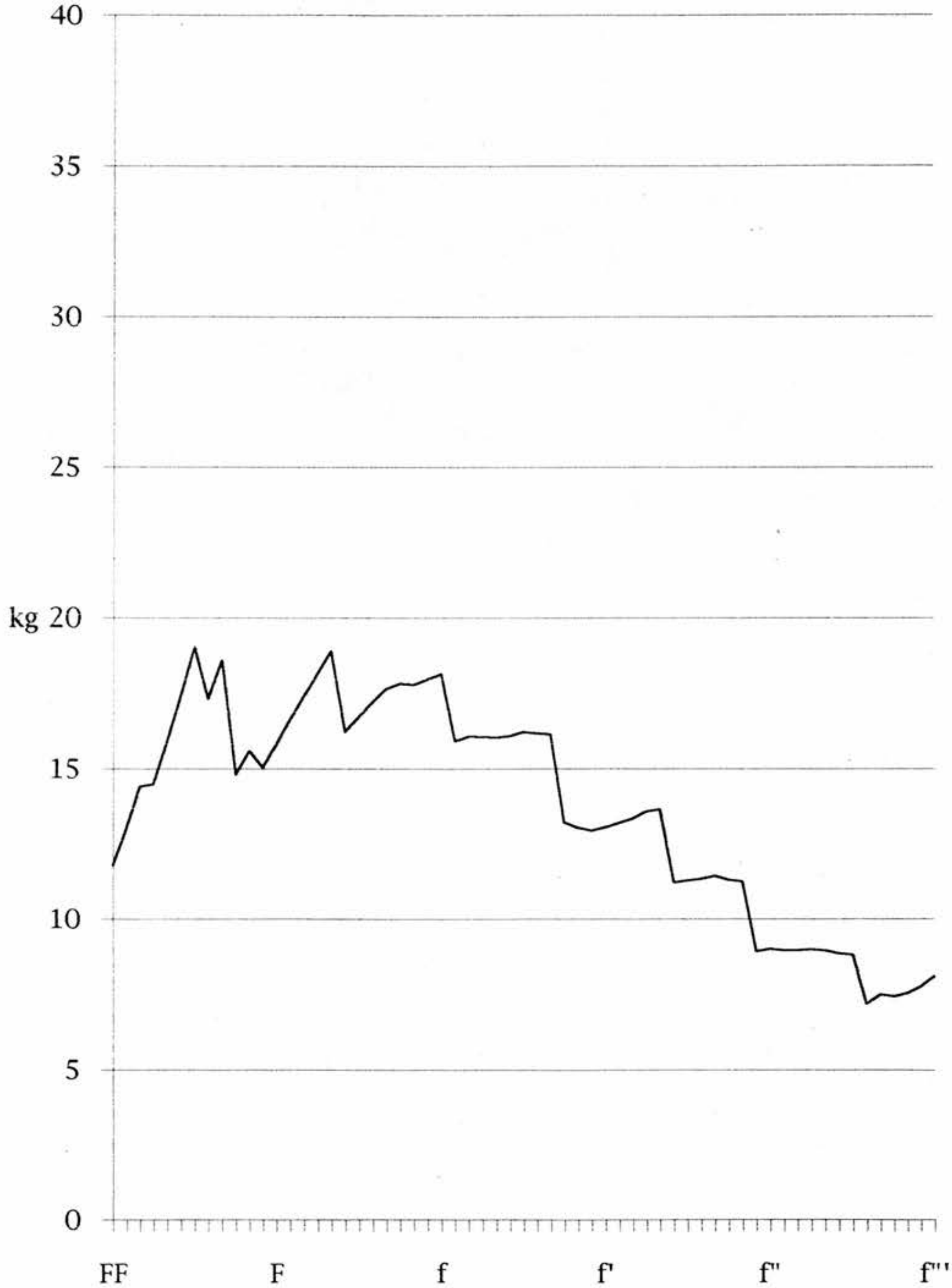
This point of view does not appear to have been shared by the

245 Samuel Wolfenden, *A Treatise on the art of Pianoforte Construction*, London 1916, 19.

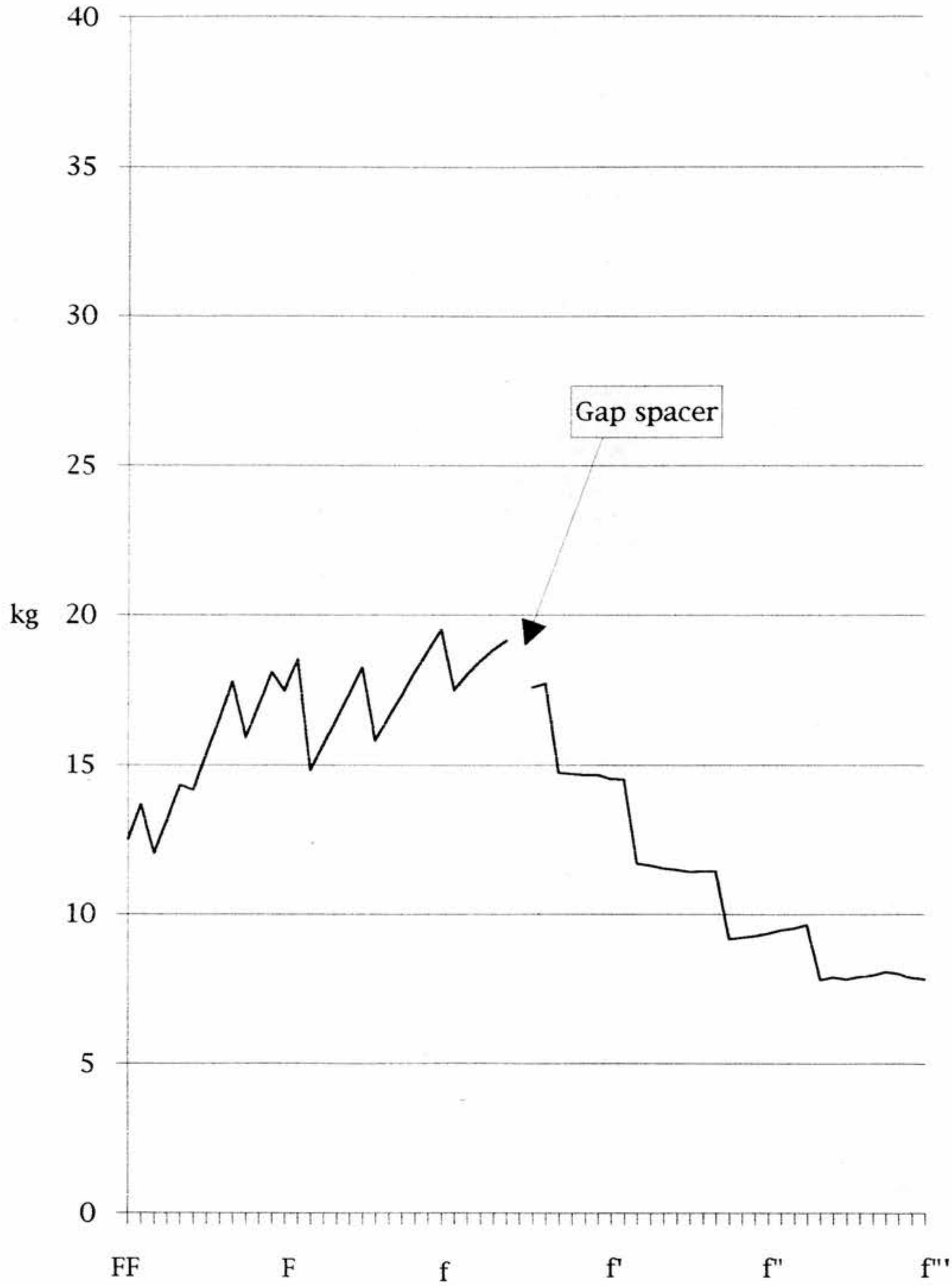
Viennese and southern German makers active between 1785 and 1820. They do not appear to striven after equality of tension. In all those pianos by the Walter firm with gauge markings the tension pattern is the same, beginning with a relatively low tension, rising fast to a high point and then decreasing in steps to about half the the maximum (graph 68). The steps are the result of the gauge changes.

The string tension distribution in the pianos of Hofmann is similar to that in the pianos by Walter although in general the maximum is reached higher in the compass, at the last note before the gap spacer (graph 69). In some cases there is a dramatic drop in tension on the treble side of the gap spacer and a slight increase in the tension in the treble where the scale is stretched (graph 70).

Grand Piano Anton Walter (W/1796)
String tensions: 1 string for each note

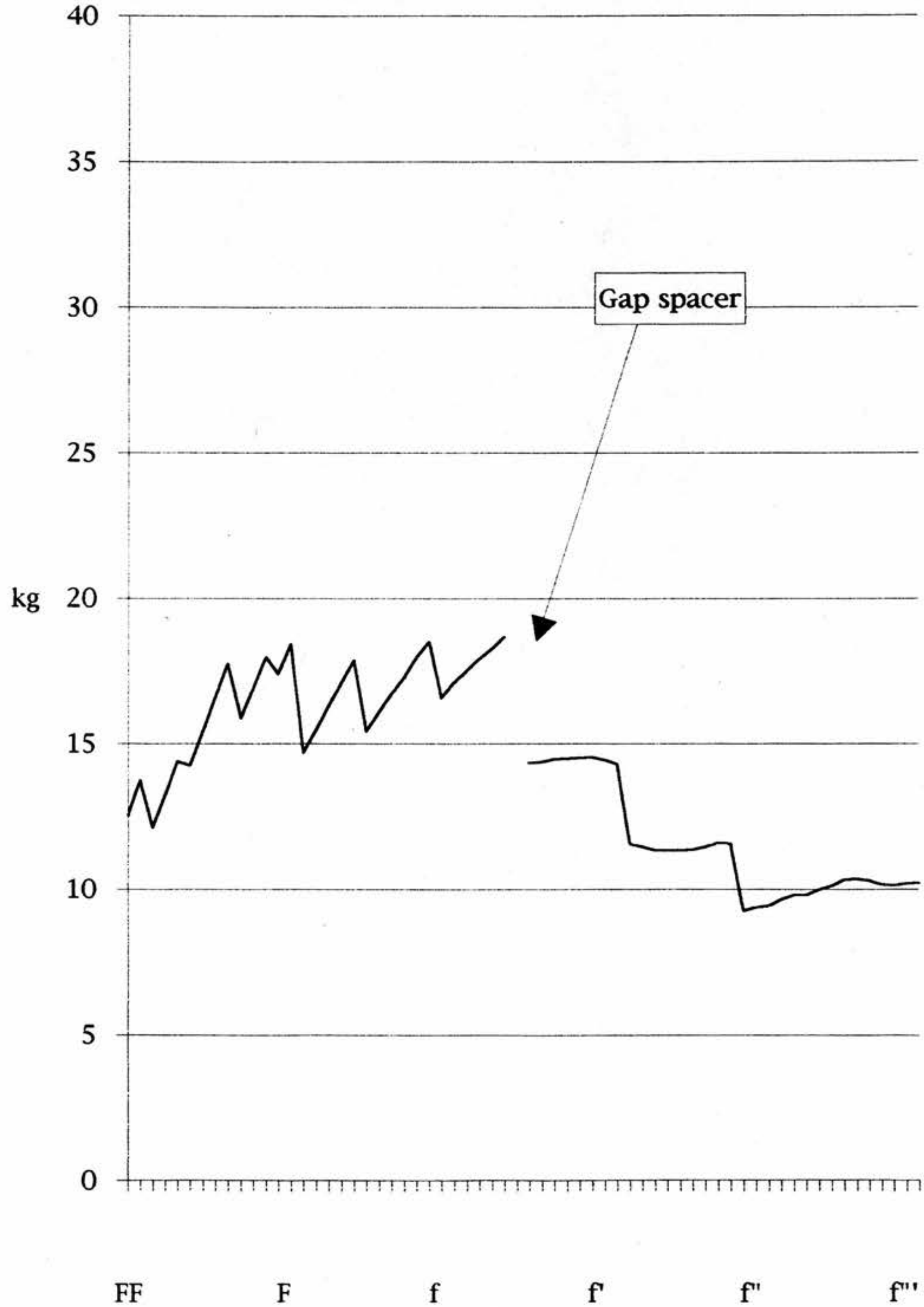


Grand piano Ferdinand Hofmann (H/c. 1790b)
String tensions: 1 string for each note



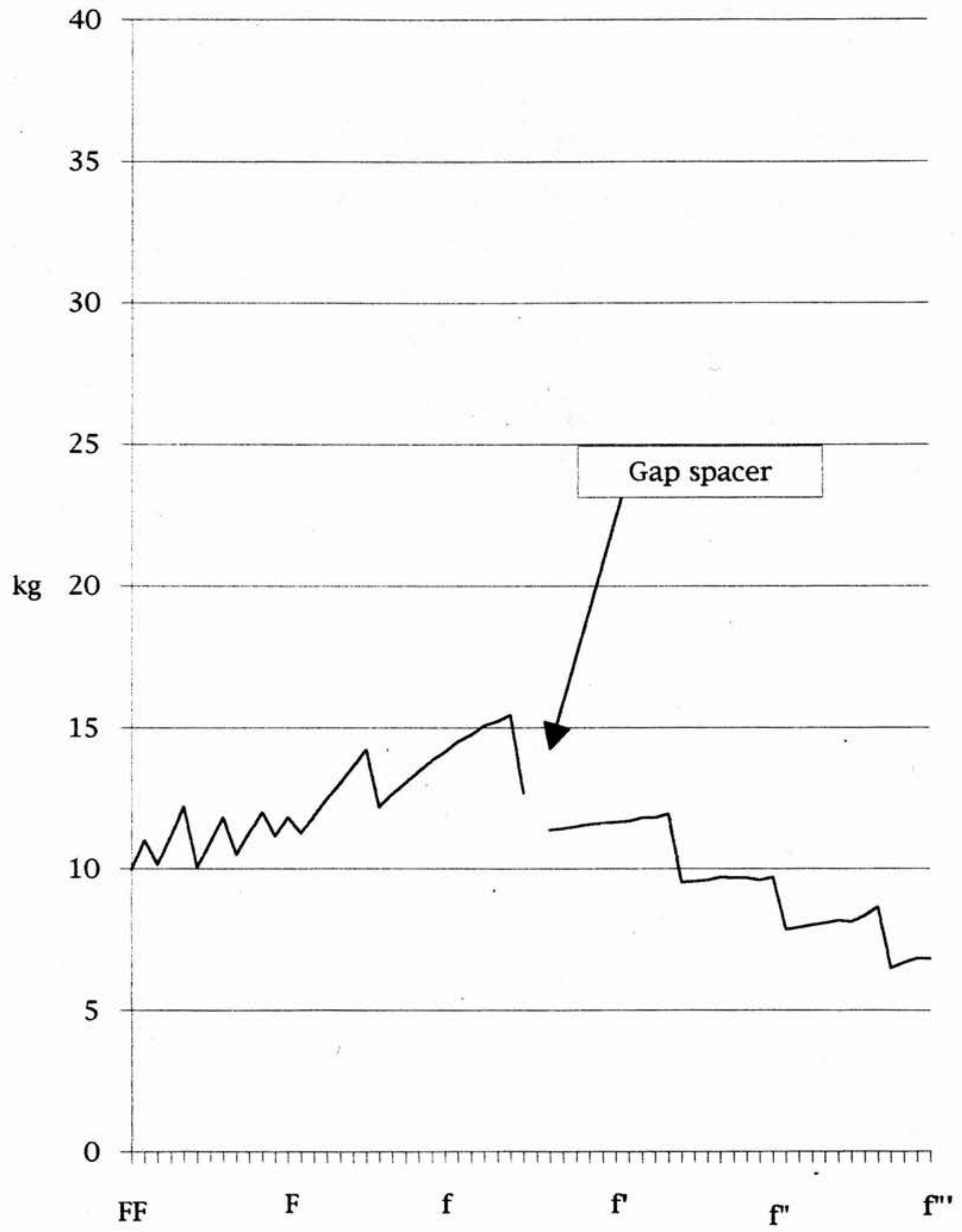
graph 69

Grand Piano Ferdinand Hofmann (H/c. 1795c)
String tensions: 1 string for each note



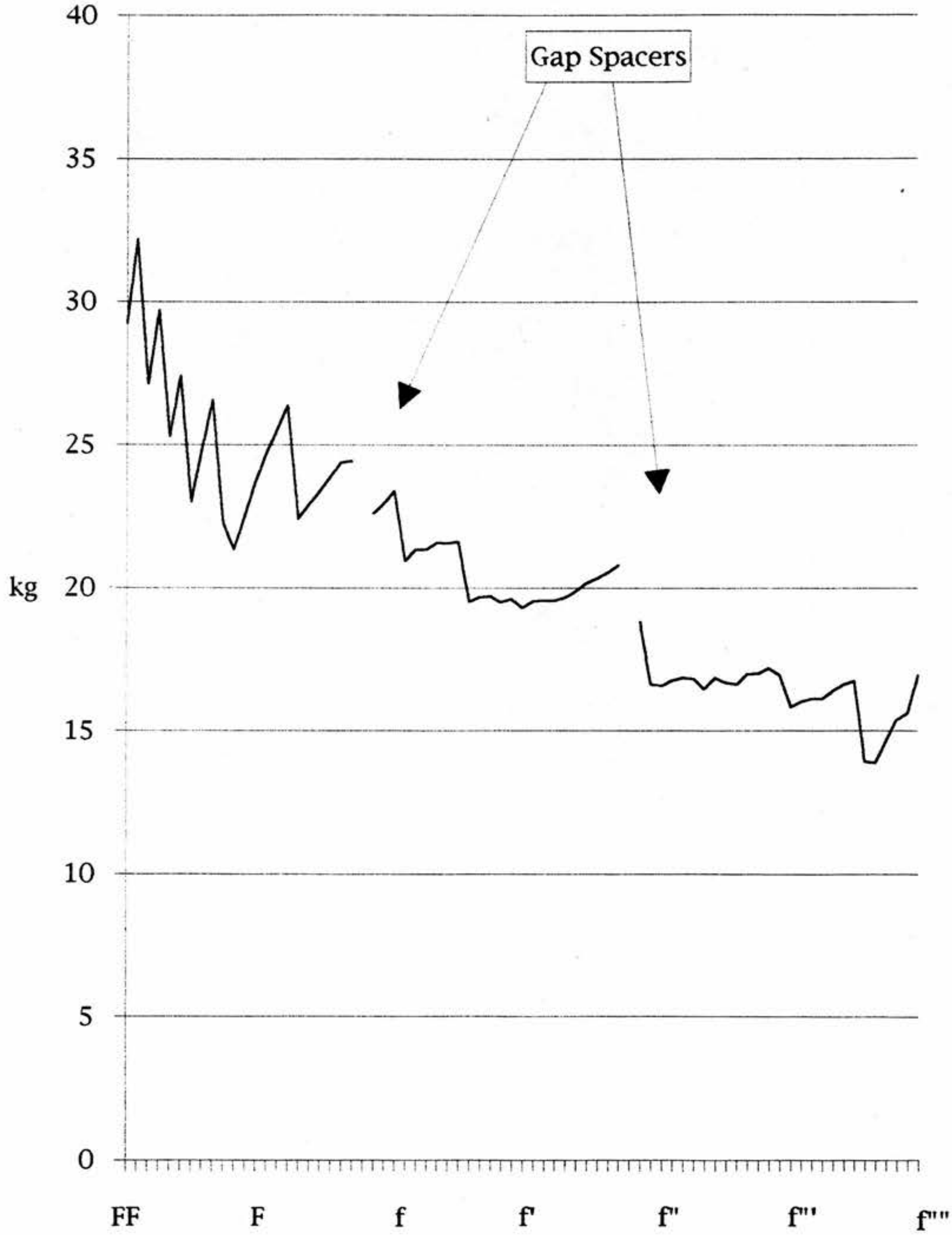
graph 70

Grand piano Johann Andreas Stein
String tensions: one string for each note
a' = 430 Hz



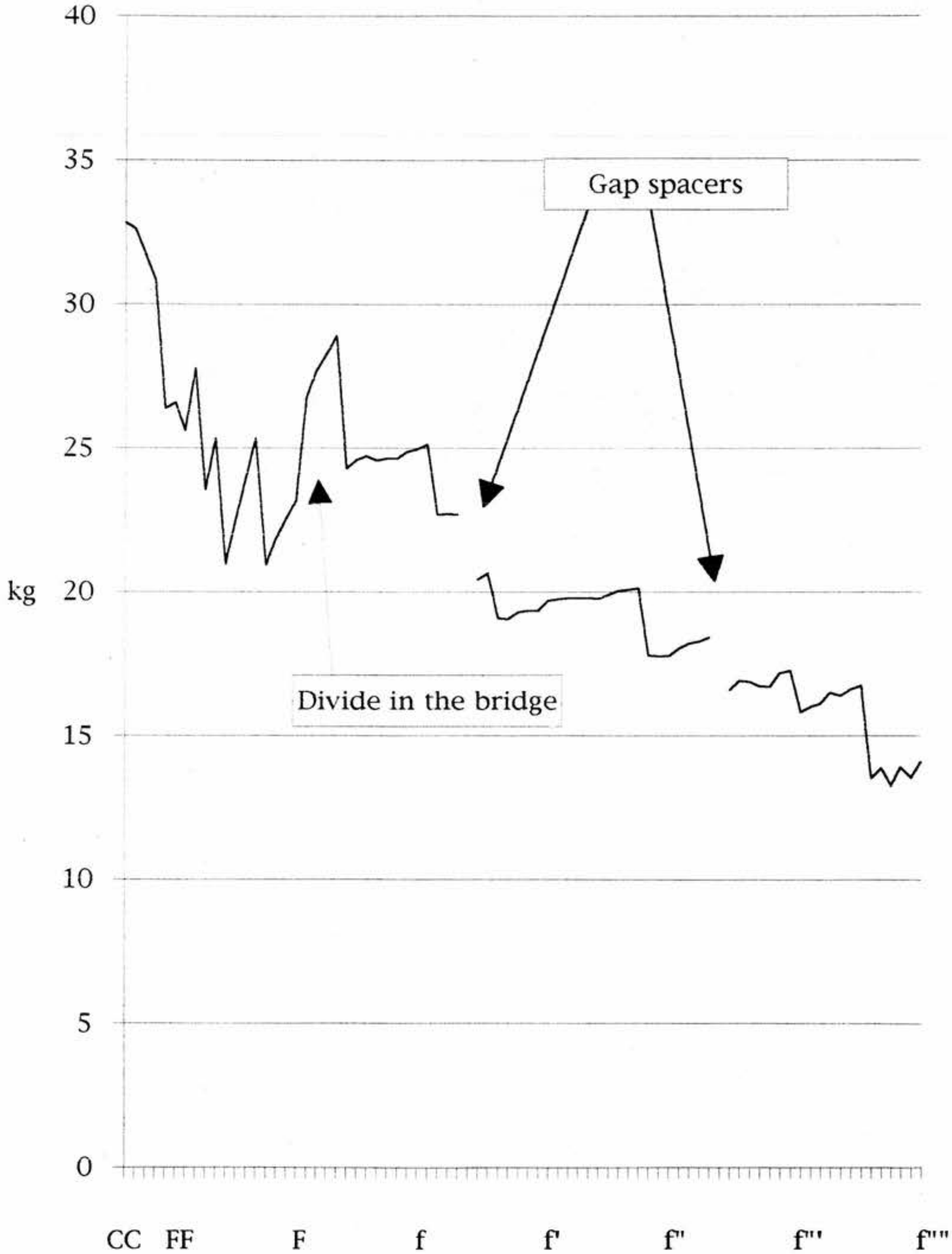
graph 71

Grand piano Nannette Streicher S/1820/1550
String tensions: 1 string for each note
a' = 430Hz



graph 72

Grand piano Nannette Streicher S/1823/1756
String tensions: 1 string for each note
a' = 430Hz



graph 73

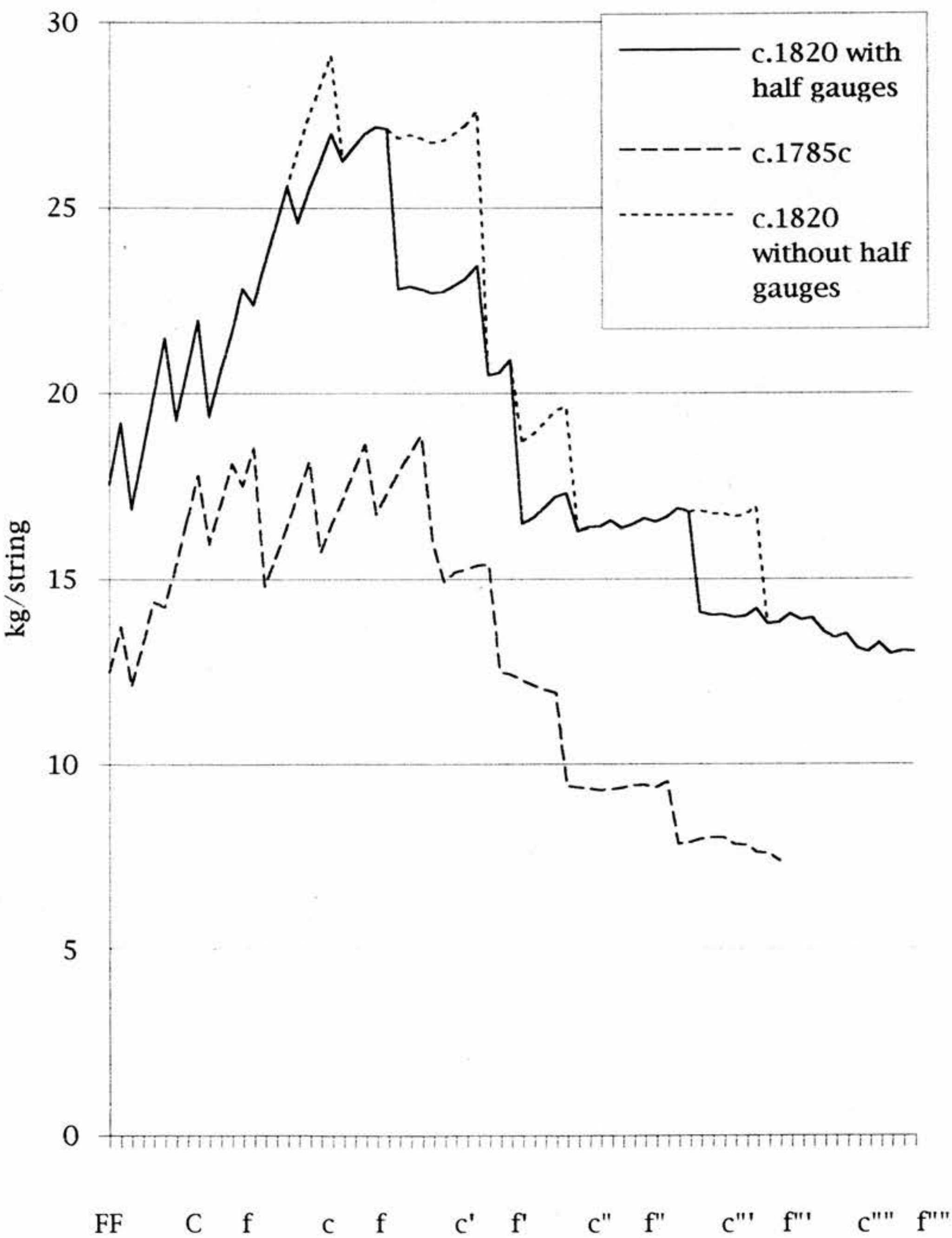
In the only piano by Stein with a complete set of string gauge markings, S/1788a, and in the earliest piano by Streicher with gauge markings, S/c.1804a, the tension in the bass is more or less equal but then rises to a maximum on the bass side of the gap spacer. There is then a decrease in the tension towards the extreme treble but finishing with a slight increase again for the last few notes where the scaling is stretched (graph 71). From 1807 onwards to 1830 the highest tension is at the lowest note (graph 72). Where there is a divided bridge there is a marked increase in tension at the divide owing to the scaling of the first iron strings, far longer than that of the last brass strings (graph 73).

Both the divided bridge and the gap spacer create sharp changes in the tension. In general, string tension is not equal. It is thus unlikely that the Viennese builders considered equal tension to be advantageous.

Evenness of tension and the introduction of half gauges

One advantage of introducing intermediate or half gauges is that the string tension differential at each gauge change becomes less exaggerated. In graph 74 the string tensions of H/c.1785c (using Thomée's Nuremberg diameters) are compared with those of H/c.1820 (using Huber's 'Berlin' diameters) and with the string tensions on H/c.1820 as if it were strung throughout with only whole number gauges (again using Huber's 'Berlin' diameters but without the half gauges). Although there are jumps in the tension at the gauge changes in both pianos when strung according to their actual gauge markings, the jumps in H/c.1820 would have been considerably greater if half gauges had not been prescribed.

Comparison of the string tensions of
two pianos by Ferdinand Hofmann
H/c.1820 and H/c.1785c
a' = 430 Hz



graph 74

CHAPTER VII

BREAKING TENSIONS

By about 1785, the piano had become established as a serious alternative to the harpsichord in German-speaking regions. From then on, a demand for more volume was probably the most important factor which directed the development of the piano. In his article on choir pitch in Schilling's '*Encyclopädie*' of 1835, Fink wrote that

> 'What one had formerly found to be too shrill [*grell*] and sharp was soon found not to be effective enough to the senses, continually more used to noisy habits.'[246]

In the same '*Encyclopädie*', *grell* is defined by Schilling as

> 'everything in general which either presents itself too loudly so that it affects the senses unpleasantly, or which contrasts too strongly or roughly with something else.'[247]

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246 '*Was man sonst zu grell und scharf gefunden hatte, wurde von dem immer mehr ans Lärmende gewöhnten Sinne bald nicht wirksam genug gefunden.*' Gustav Schilling, ed., *Encyclopädie der gesammten musikalischen Wissenschaften, oder Universal-Lexicon der Tonkunst*, II, Stuttgart 1835, 233.

247 '*Grell ist überhaupt Alles, was entweder an und für sich zu stark hervortritt, so daß es die Sinne unangenehm afficirt, oder was...mit einem Anderen zu stark oder schroff contrastirt.*' Gustav Schilling, ed., *Encyclopädie der gesammten musikalischen Wissenschaften, oder Universal-Lexicon der Tonkunst*, II, Stuttgart 1835, 303.

The acoustic power of a string is proportional to the fourth power of its diameter, so it is not surprising that as time went on, the strings used were of larger diameters. In general, the later the instrument, the thicker the strings.

Breaking tensions and the shortening of the scaling

The three possible reasons for shortening the thicker strings should be reiterated here. One reason is that if thicker strings are used, the total tension on the case of the instrument will be increased. An excess total tension in relation to the case structure can be avoided by strengthening the case or by shortening the strings, reducing the danger of case distortion and failure. Another reason for shortening the scaling is that a rise in pitch can bring the strings too close to breaking point. This danger can be avoided by shortening the strings appropriately. But the most important reason for shortening the scaling, dealt with now, has to do with the phenomenon known as tensile pick-up. As wire is drawn down it becomes work-hardened, assuming that there is no annealing during the drawing process.[248] The thinner the wire the stronger it

248 The difference between breaking tension and tensile strength should be noted. Breaking tension is the tension, usually measured in Newtons or kg, at which a wire breaks. Tensile strength is the tension at which a wire breaks expressed per unit area and is usually measured in Newtons/mm^2 or Megapascals. Wire of a thinner diameter has a higher tensile strength than a thicker one but will break at a lower tension.

becomes. Conversely, thicker strings are relatively weak compared to thinner ones. By using thicker strings to obtain more volume the danger of the strings being too close to breaking point increases, a danger reduced by shortening the strings.

Although there was no single source of wire and the quality of the obtainable wire varied considerably in Vienna some artificial standards relating to the tensile strength of that wire have to be fixed in order to calculate and compare the proximity of the strings to breaking point. How close a string is to breaking point can be described by calculating the string tension and expressing it as a percentage of the breaking tension. If, for instance, the tension on a string is 12kg and the breaking tension of the wire is 15kg the string is stressed to 80% of its breaking tension. A string at 90% of its breaking tension is only about a semitone away from breaking, at 80% at about two semitones away from breaking, at 70% three semitones away from breaking and at 63% four semitones away from breaking.

The assumptions made to arrive at the percentage proximity of a string to breaking point are wide ranging and must be taken into account when assessing the validity of any conclusions drawn regarding the extent to which the strings on a particular piano are stressed. This is a matter of some importance to the present essay. For this reason these assumptions are listed here again.

i) The standard pitch for all the pianos discussed here is assumed to be a' = 430Hz even though in practice the pitches used varied widely, especially geographically.

ii) The absolute diameters of the string gauges, which in practice probably varied considerably both in time and from one wire drawer to the next, must be arbitrarily fixed. The gauge markings on instruments made before 1820 are assumed here to refer to the diameters of Thomée's Nuremberg gauge system while the gauge markings found on instruments made after 1820 are assumed to refer to the diameters of Huber's 'Berlin' gauge system.[249]

iii) Consistency of the tensile strength of each gauge of wire is assumed. In practice the tensile strength of the wire probably also varied considerably. The standard tensile strengths used here were established by experiments conducted by Alfons Huber and the author in the laboratory of the Technical University in Vienna. These experiments are now briefly outlined.[250]

Establishing standard breaking tensions

Limited samples of old wire from an instrument by Hofmann (H/c.1800) were taken as representative of the wire used before 1820 and similar samples from an instrument of about 1826 by

249 For the Nuremberg diameters see H. Thomée, 'Untersuchungen über Draht- und Blechlehren', *Zeitschrift des Vereines Deutscher Ingineure,* X, 1866, 659-60. For the mm equivalents see table 8 above. For Huber's 'Berlin' diameters see Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 217. For the mm equivalents see table 19 above.

250 A detailed report of this work will be published in a forthcoming paper.

Graf were taken to represent the wire used after 1820.[251] The following procedure was adopted to test the tensile strength of the wire and of the tensile pick-up of the samples when drawn down to thinner diameters.

The breaking tensions of one thick and one thin sample of original wire from one instrument were measured. As expected, the thinner sample was found to have a relatively higher tensile strength than the thicker sample. The thicker sample was then drawn down in a series of steps to the diameter of the thinner sample. At each step, the breaking tension of the wire was measured.[252]

When drawn down to the diameter of the thinner sample, the thicker sample was found to have a breaking tension which closely approximated the breaking tension of the thinner original sample. It could thus reasonably be concluded that the two original samples came from the same stock and that no annealing took place during the original drawing process.

It was also found that for the set of sizes of wire obtained by drawing down the original thicker sample, the breaking tension varied with diameter in a relationship closely approximating direct proportion.[253] Assuming the same to be true of the original wire it

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251 The piano by Graf is {c.1826/609}.

252 Where possible each diameter was tested at least three times.

253 The same was found to be true of other samples of old iron wire, of later iron wire and of brass wire. The breaking tensions given by Malcolm Rose for his iron wire also vary in direct proportion to their diameters. See Malcolm Rose and David Law, *A handbook of Historical Stringing Practice for Keyboard Instruments*, Lewes and Long Compton 1991.

was thus possible to use the breaking tensions of the thinner and thicker original samples to calculate the breaking tensions for any given diameter of original wire. By using the breaking tensions of the two samples of wire from H/c.1800 breaking tensions were calculated for each of the diameters given by Thomée for his Nuremberg system. These breaking tensions have been used as the standard breaking tensions for iron wire used before 1820.

By repeating the same process using the two samples from the c.1826 piano by Graf breaking tensions were calculated for the diameters given by Huber for his 'Berlin' system. These have been used as standard breaking tensions for iron wire used after 1820.

Samples of brass wire from H/c.1800 were also tested in a similar way to give a series of standard breaking tensions for brass wire of before 1820. Only one sample of brass wire from an instrument likely to have been strung with 'Berlin' wire was available. This Viennese instrument is a square piano by Joseph Knam built in about 1825 privately owned in The Netherlands. The single wire was drawn down to give a series of thinner diameters. At each step the breaking tension was again measured. The resulting set of breaking tensions for each gauge were used as the standard breaking tensions for brass wire used after 1820.

The two series of breaking tensions thus obtained, one for wire of before 1820 (Thomée's Nuremberg diameters) and one for wire of after 1820 (Huber's 'Berlin' diameters), given in tables 73 and 74, have been used here for the calculations of the proximity of strings to breaking point. As expected, a comparison of the two sets of breaking tensions shows that the later wire is the stronger.

Breaking tensions for brass wire of before and after 1820

Before 1820			After 1820		
Gauge	Diameter (mm)	Breaking tension (kg)	Gauge	Diameter (mm)	Breaking tension (kg)
11/0	1.30	55.4			
10/0	1.42	50.2	10/0	1.58	76.6
9/0	1.10	41.6	9/0	1.44	69.5
8/0	1.06	39.9	8/0	1.30	62.5
7/0	0.97	36.0	7/0	1.14	54.5
6/0	0.87	31.7	6/0	1.01	48.0
5/0	0.83	30.0	5/0	0.89	42.0
4/0	0.76	27.0	4/0	0.79	37.0
3/0	0.66	22.7			
2/0	0.60	20.1			
1/0	0.56	18.4			

Table 73

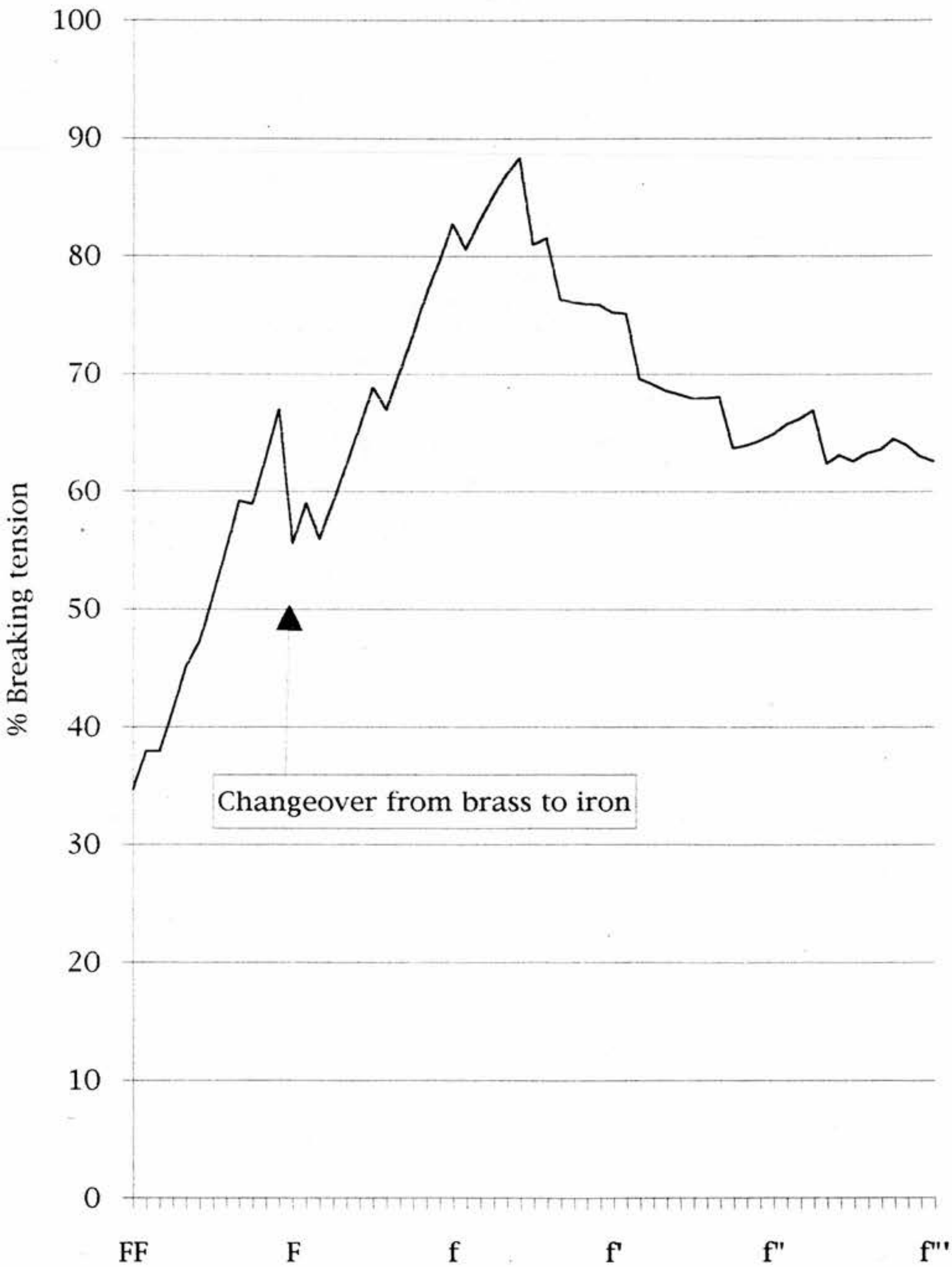
Breaking tensions for iron wire of before and after 1820

Before 1820			After 1820		
Gauge	Diameter (mm)	Breaking tension (kg)	Gauge	Diameter (mm)	Breaking tension (kg)
			6/0	1.01	53.3
			6/0½	0.95	49.3
			5/0	0.89	45.2
			5/0½	0.85	42.5
4/0	0.76	31.4	4/0	0.79	38.5
			4/0½	0.76	36.5
3/0	0.66	26.5	3/0	0.72	33.8
			3/0½	0.68	31.1
2/0	0.60	23.6	2/0	0.65	29.1
			2/0½	0.61	26.4
1/0	0.56	21.7	1/0	0.59	25.1
			1/0½	0.55	22.4
1	0.51	19.3	1	0.53	21.1
			1½	0.50	19.0
2	0.46	16.8	2	0.47	17.0
3	0.41	14.4			
4	0.37	12.5			
5	0.32	10.0			

Table 74

Knowing the pitch, the string lengths and the string diameters of a particular piano a graph can be made of the proximity of the strings to breaking point. As an example, such a graph is here given for the strings of a piano by Hofmann, H/c.1790b (graph 75). The pitch is assumed to be a' = 430Hz, the string diameters are assumed to conform to Thomée's Nuremberg gauge diameters and the breaking tensions of those diameters are assumed to be the same as those given in tables 73 and 74 for wire of before 1820. Because of the hypothetical nature of these assumptions such a graph cannot be used for practical purposes. The value of such a graph lies more in its use for qualitative comparison. It is possible, for instance to say that the area in which the strings are closest to breaking point lies in the middle of the compass. It is also possible to say that the extent to which the strings are stressed is by no means even, that the stress differentials between the extremes of the compass and the middle of the compass are considerable. But it is not possible to say, for instance, that at 90% the strings in the middle of the compass are too close to breaking point. The nature of the assumptions involved make such quantitative and absolute assertions invalid.

Grand Piano Ferdinand Hofmann (H/c.1790b)
Proximity of the strings to breaking tension
a' = 430Hz

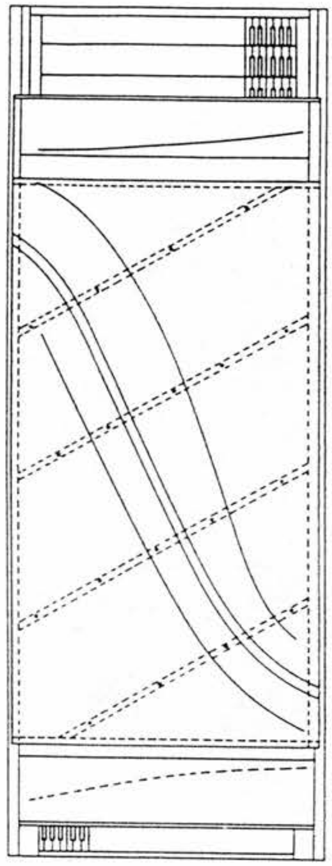


graph 75

The qualitative comparison of the extent to which the strings are stressed, both in a single instrument and between different instruments, can help to elucidate some features of stringing and scaling. The necessity of shortening thicker strings, the change to a thinner gauge for only a few notes in the extreme treble, the changeover from brass to iron strings and the use of the divided bridge may all be more easily understood by estimating how close the strings are to breaking point. The comparison of the extent to which the strings are stressed in the different instruments of one maker and in the instruments of different makers may offer insight into the varied development of piano design.

The relationship between string diameter, string length and the extent to which the strings are stressed: Stein's *vis-à-vis* instrument of 1777

The scalings of late eighteenth-century pianos are usually far shorter than the scalings of the harpsichords of the same period. The *vis-à-vis* harpsichord-piano by Stein (S/c.1777) provides an interesting case in point. This instrument, made in 1777, combines a harpsichord and a piano opposite each other such that they share a common bentside (ill. 20). The name *vis-à-vis* is derived from the fact that the two players sit facing each other. Although the two instruments are combined, each has its own soundboard and set of strings. The lengths of the longest of the three sets of 8' strings of the harpsichord are compared with the lengths of the piano strings in table 75. The string lengths of the harpsichord are considerably longer than those of the piano.



ill. 20 A plan view drawing of the *vis-à-vis* instrument by Stein of 1777. The harpsichord has three keyboards of which the lowest serves the piano at the other end. The other two manuals are for the harpsichord which has the following registers: 16', 8', 8' and a third 8' which is a 4' on its own bridge in the bass. In this sketch, the 16' and 4' bridges and nuts have been omitted for the sake of clarity. The internal construction is shown with broken lines. The diagonal braces are glued to the baseboard and to the case sides or one of the bellyrails. The shared hitchpin rail is supported underneath by a curved liner that is suspended above the baseboard and jointed to the lower braces.

The *vis-à-vis* Harpsichord-Piano by Stein of 1777
Comparison of the scalings

	Harpsichord longest 8' (mm)	Piano long string (mm)
FF	1650	1442
C	1534	1255
F	1353	1129
c	1094	918
f	892	767
c'	641	565
f'	487	432
c''	336	297
f''	255	226
c'''	171	154
f'''	124	115

Table 75

In the *Augsburger Intelligenzblatt*, No. 40, of 5 October 1769, there is a description of another instrument invented by Stein, the *Poly-Toni-Clavichordium*, which also combined a piano with a harpsichord. In this instrument however, the piano was situated under the harpsichord such that the two instruments shared a common baseboard. In the description it is stated that

> 'The combination of the piano and the harpsichord essentially consists in the possibility of coupling both instruments on one keyboard, even though each has its own case and strings. Accordingly, this work is not like those in which the hammers and the jacks share the same strings. These produce an unpleasant sound. This is because the blow of the hammer requires completely different string lengths and other strings than the jacks. There are thus two instruments together in one, separated from each other by a baseboard in the middle.'[254]

The 1769 *Poly-Toni-Clavichordium*, like the 1777 *vis-à-vis* instrument, had different scalings for the harpsichord and the piano. From the evidence in Stein's notebook we can assume that the piano had thicker ('other') strings than those of the harpsichord.

Although there are no gauge markings on the piano of the

254 '*Diese vorhin gedachte Verbindung aber bestehet weiter in nichts, als daß beyde auf einem Claviere gekoppelt werden können; denn jedes hat seinen besondern Körper und Saiten. Es ist dieses Werk demnach nicht von der Gattung derjenigen, wo die Hämmer und Doken einerlei Saiten miteinander gemein haben und eine unannehmliche Musik hervor bringen, weil der Anschlag der Hämmer eine ganz andere Mensur, und andere Saiten verlangt, als die Doken. Es befinden sich also zwey Instrumente in einem beysammen, und sind in der Mitte durch einen Boden von einander abgesondert.*' *Augsburger Intelligenzblatt*, No. 40, 5 October 1769, no page numbers, item 13, *Gelehrte Sachen.*

vis-à-vis instrument there is a stringing scheme for a '*Piano forte*' on page 248 of Stein's notebook, probably entered not long before his invention of the *vis-à-vis* in 1777. This stringing scheme is given in the notebook as follows:

Piano forte

F	G	H	D	F$^{\#}$
00000	0000	000	00	*Weiss*
c	a	a'	a"	d$^{\#}$
1	2	3	4	5

This scheme is almost identical to the three stringing schemes which have survived on Stein's pianos, those on S/1786, S/1782 and S/1788a (table 76). Only the set of gauge markings on the latter piano is complete.

Stringing schemes for pianos used by Stein

Gauge	Notebook (c.1777)	S/1782	S/1788a	S/1786
5/O	FF	FF	FF	FF
4/O	GG	GG	GG	GG
3/O	AA#	AA	AA#	AA#
2/O	D	C	C#	D
O	-	E	E	E
O (iron)	F#	?	F#	-
1	c	?	c	c?
2	a	?	b	?
3	a'	?	a#'	?
4	a"	?	f#"	?
5	d#"'	?	d"'	?

Table 76

The similarities between the notebook list and the gauge markings found on the three pianos show that Stein probably did not appreciably change the string gauges he used for grand pianos from at least as early as 1777 to at least as late as 1788.[255] It is therefore reasonable to assume that the piano of the *vis-à-vis* instrument was strung according to the scheme found in the notebook on page 248.

Unlike the piano, the harpsichord of the *vis-à-vis* instrument does have gauge markings for the 8' strings. In table 77 these are compared with the stringing scheme for a 'large harpsichord' found on page 251 of the notebook.

255 This assumes that the notebook list and the markings found on the three pianos all refer to the same string diameters. The string lengths of S/c.1777, S/1786 and S/1788a are very similar: their c" lengths are 302mm, 302mm and 296mm respectively.

Comparison of the gauge markings found on the harpsichord of S/1777
with the gauges given in Stein's notebook for a large harpsichord

Gauge	*..grosses flügels* (notebook, p. 251)	*vis-à-vis* 1777 (Verona)
2/0	FF	FF
0	GG	FF#
1	AA#	GG#
2	C#	AA#
3	E	C#
4	G	D#
5	B	F#
6	c	A#
6 *Weiss*	c#	-
7	f	d#
8	c'	a#
9	c''	a#'
10	c'''	-

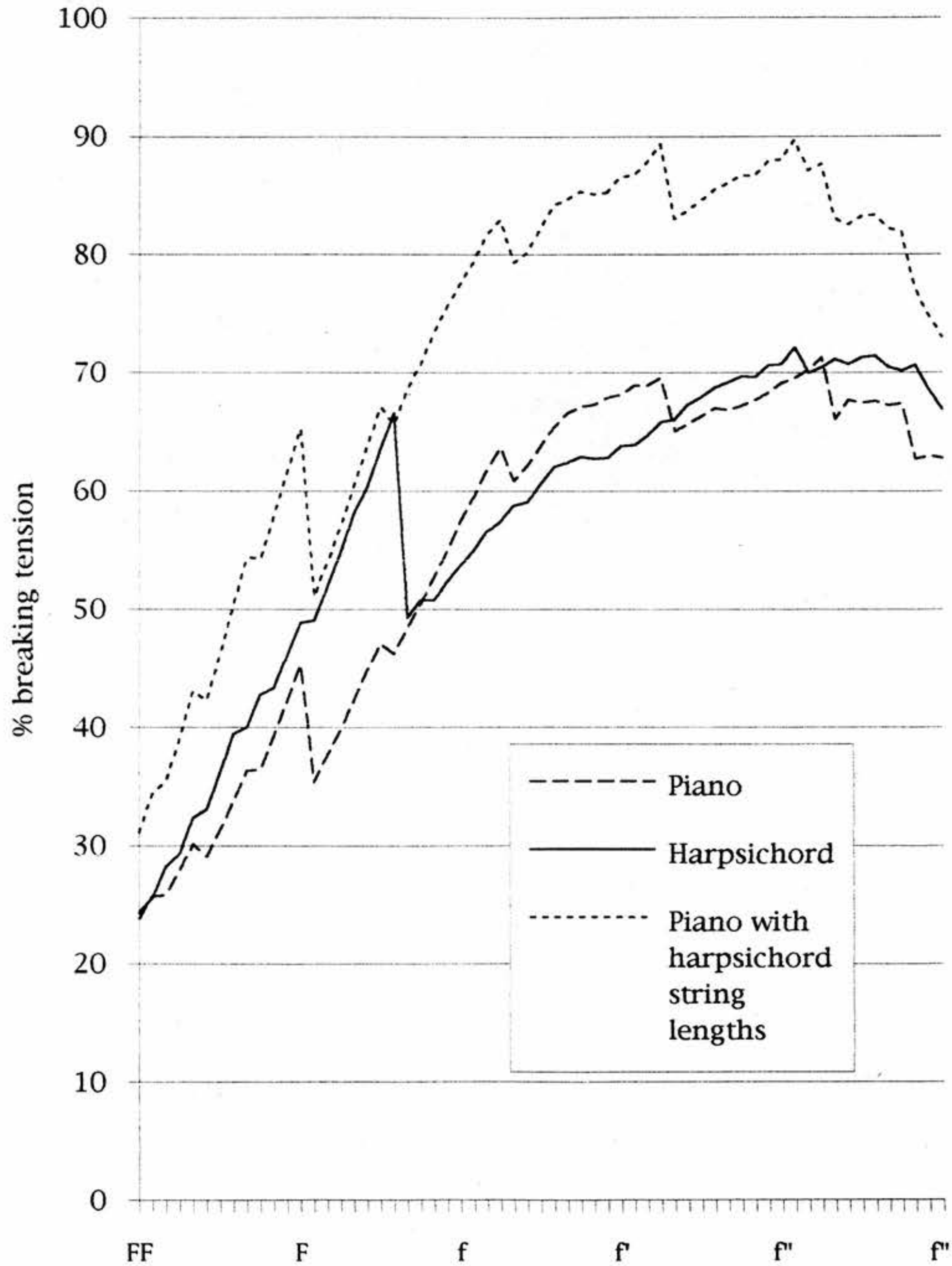
Table 77

The stringing of the *vis-à-vis* harpsichord is slightly heavier than indicated by the scheme given in the notebook (page 251) but both are considerably lighter than the stringing scheme on the piano of 1788 (S/1788a) and the scheme given for the piano in the notebook (page 248). Stein strung his harpsichords with longer thinner strings and his pianos with shorter thicker strings. On the basis of these and a few more assumptions we are now in a position to compare the proximity of the strings to breaking point on the harpsichord and the piano of the *vis-à-vis* instrument.

In the stringing scheme for a harpsichord in his notebook (page 251) Stein specifies iron strings from c# upwards by repeating gauge 6, and in the scheme for a piano (page 248) from F# upwards by using the word *Weiss*. It is assumed here that yellow brass was used for the strings of the bass in both the piano and the harpsichord of the *vis-à-vis* instrument and that in the harpsichord the brass was also taken up to the note c, as in the stringing scheme for a harpsichord in the notebook.

It is also assumed that the diameters of the wire used for both the harpsichord and the piano were those given by Thomée for Nuremberg wire and that the breaking tensions of the different gauges are those given in tables 73 and 74. Finally, it is assumed that both instruments were tuned to the same pitch, a' = 430 Hz. The pattern of the proximity of the strings to breaking point, calculated on the basis of these assumptions, is given in graph 76. Generally, the shorter thicker piano strings are stressed to the same degree as the longer thinner harpsichord strings.

The vis-à-vis instrument (S/1777) by Stein
Proximity of the strings to breaking point
a' = 430Hz



graph 76

If the strings of the piano had been as long as those on the harpsichord, but still using the thicker piano gauges, the strings would have been closer to breaking point than those on the harpsichord. Graph 76 shows the effect of combining the harpsichord string lengths with the piano string diameters. This would have resulted in some strings being stressed to within 90% of breaking point. It seems to be the case that because he used thicker strings on the piano, Stein had to shorten them in order to maintain the same proximity to breaking point. Stein must have been aware of the converse effect of tensile pick-up: thicker strings are weaker and therefore have to be made shorter if a desired safety margin with respect to string breakage is to be maintained. Except at the change-over from brass to iron, Stein appears to have carefully taken into account the different tensile strengths of the string gauges he used when designing the scalings of the harpsichord and the piano of his 1777 *vis-à-vis* instrument.

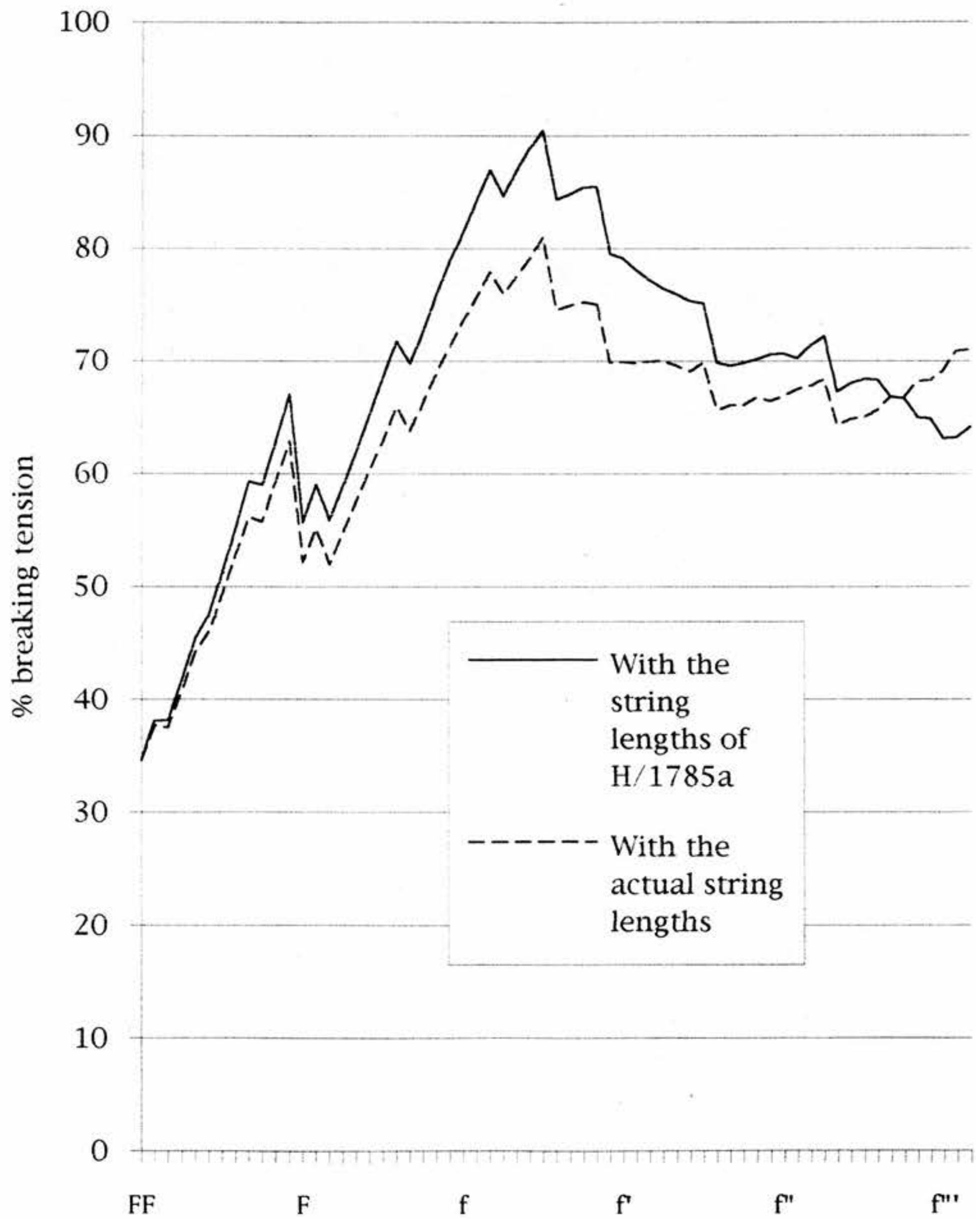
The relationship between string diameter, string length and the extent to which the strings are stressed: Hofmann's pianos

It is true to say that for Hofmann's pianos the later the instrument the thicker and shorter the strings. The effect on the proximity of the strings to breaking point of not shortening the thicker strings of the later instruments is shown in the following two examples. In the first the effect is shown of using the longer scaling of

H/c.1785a in conjunction with the thicker gauges of H/c.1800. The strings in the middle of the compass would have been 10% closer to breaking point if the strings of H/c.1800 had not been shortened (graph 77). By shortening the thicker strings, Hofmann avoided an increase in the extent to which the strings were stressed in the middle of the compass by an amount equivalent to about a semitone.

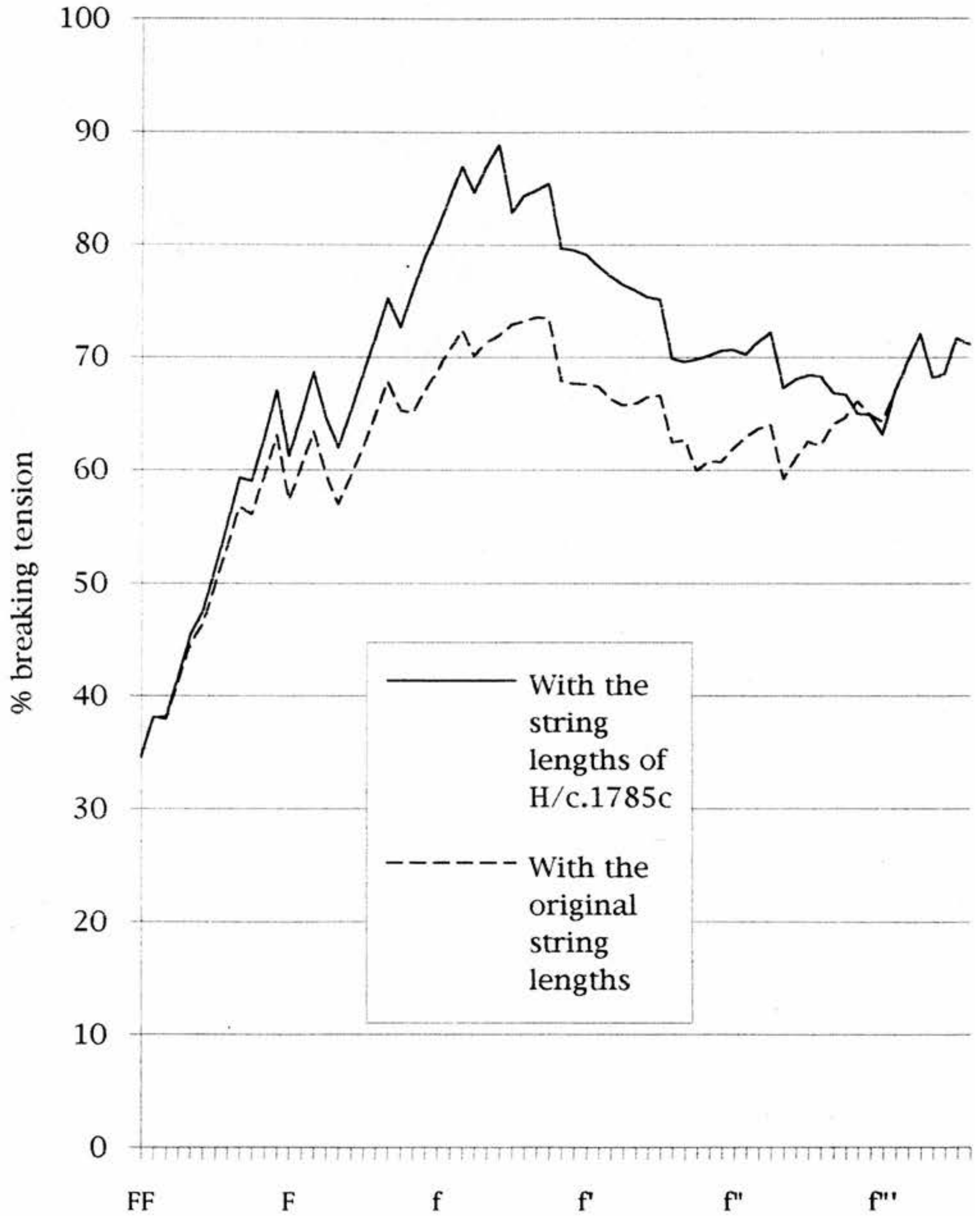
The effect of shortening the thicker strings is even clearer if H/c.1785c is compared with H/c.1805. If the string lengths of H/c.1785c are combined with the string gauges of H/c.1805, that is if Hofmann had not shortened the thicker strings of the c.1805 instrument, the maximum proximity of the strings to breaking point would have been increased by 20%, equivalent to about two semitones (graph 78).

Grand Piano Ferdinand Hofmann (H/c.1800)
Proximity of the strings to breaking point
with the actual string lengths and with the
string lengths of H/1785a
a' = 430Hz



graph 77

Grand Piano Ferdinand Hofmann (H/c.1805)
Proximity of the strings to breaking point
with the original string lengths and with the
string lengths of H/c.1785c
a' = 430Hz



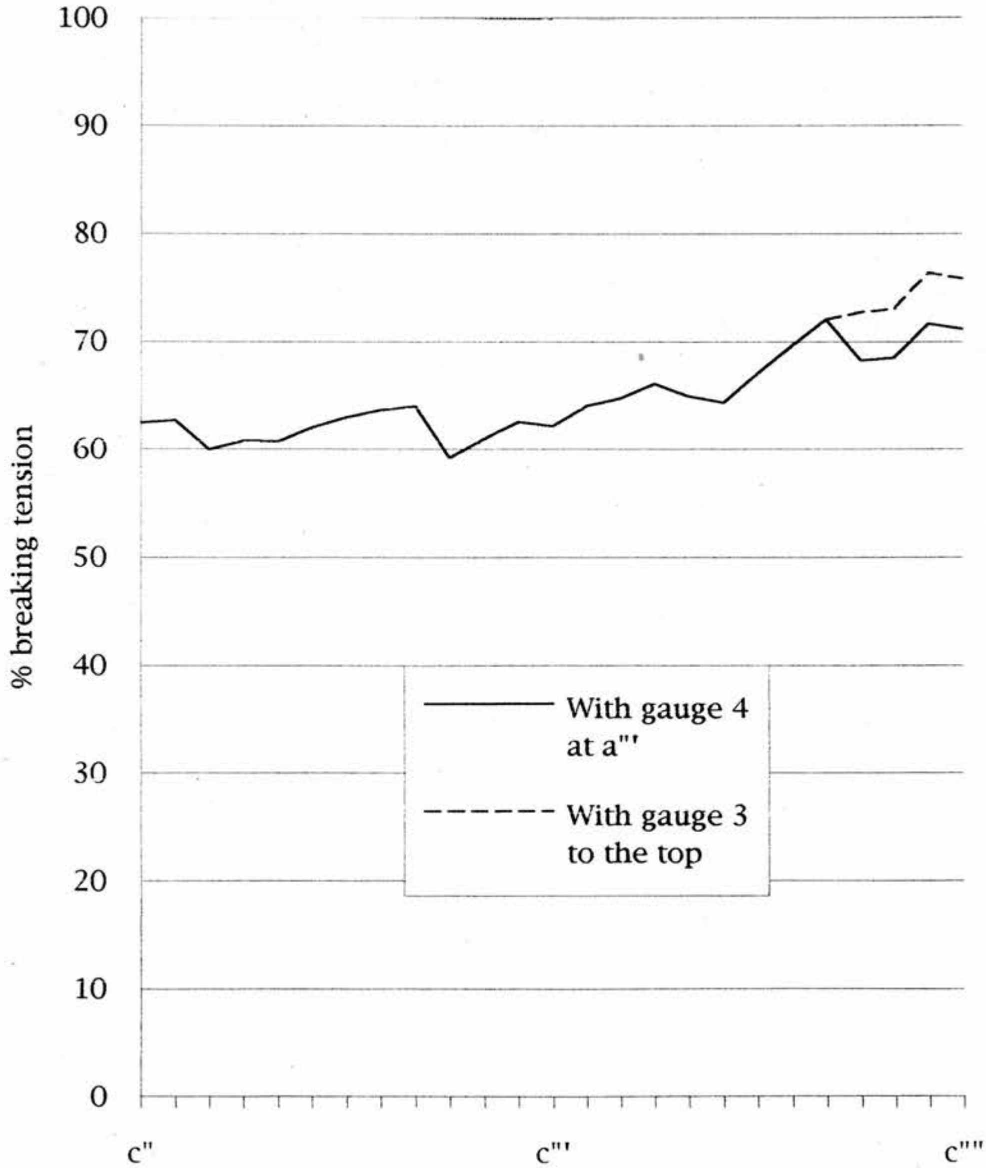
graph 78

The choice of a thinner gauge for a few notes in the treble and the effect on the extent to which they are stressed

In a number of Viennese instruments there is a change to a thinner gauge for just the top few notes. The scaling is often stretched in the extreme treble and a change to a thinner diameter may have been made to keep the strings to within a desired safety margin with respect to breaking point. In graph 79, the effect of continuing gauge 3 to the top of the compass of H/c.1805 is compared with the actual situation in which there is a change to gauge 4 at a''', that is, for only the top four notes. It will be noted that although the change in the proximity to breaking point is not very great, it is enough to maintain the maximum proximity to breaking point already established in the treble, whereas without the change to gauge 4 the maximum would have been increased somewhat.

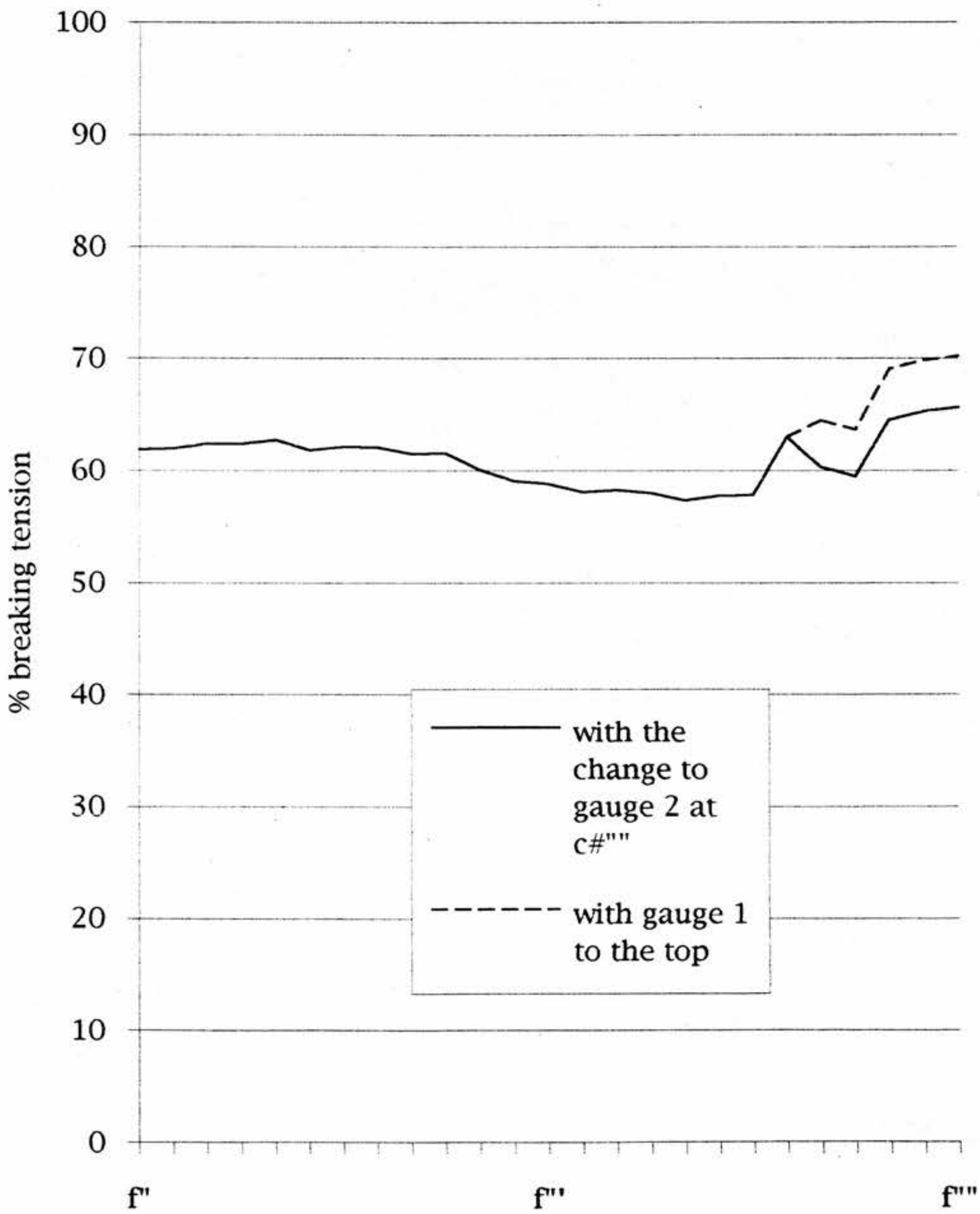
The change to a thinner gauge may not be related to treble stretching however. This illustrated by the pianos of the Streicher firm. All their pianos of before about 1835 with gauge markings have a change to a thinner gauge (gauge 1, $1^1/_2$ or 2) for only the last four to six notes. But none of the pianos by Streicher made between about 1804 and 1820 has a stretched treble scaling. This suggests that the change to a thinner gauge may simply have been made for acoustic reasons rather than to maintain the strings at a particular stress level or to avoid string breakage. The effect of continuing gauge 1 to the top of the compass instead of changing to gauge 2 in S/1808/764 is shown in graph 80.

Grand Piano Ferdinand Hofmann (H/c.1805)
Proximity of the top two octaves of strings to breaking tension
with the change to gauge 4 at a'''
and with the situation if gauge 3 were continued to the top



graph 79

Grand Piano by Nannette Streicher
(S/1808/764)
Proximity of the top two octaves of strings to
breaking point
with and without the change to gauge 2 at c#""



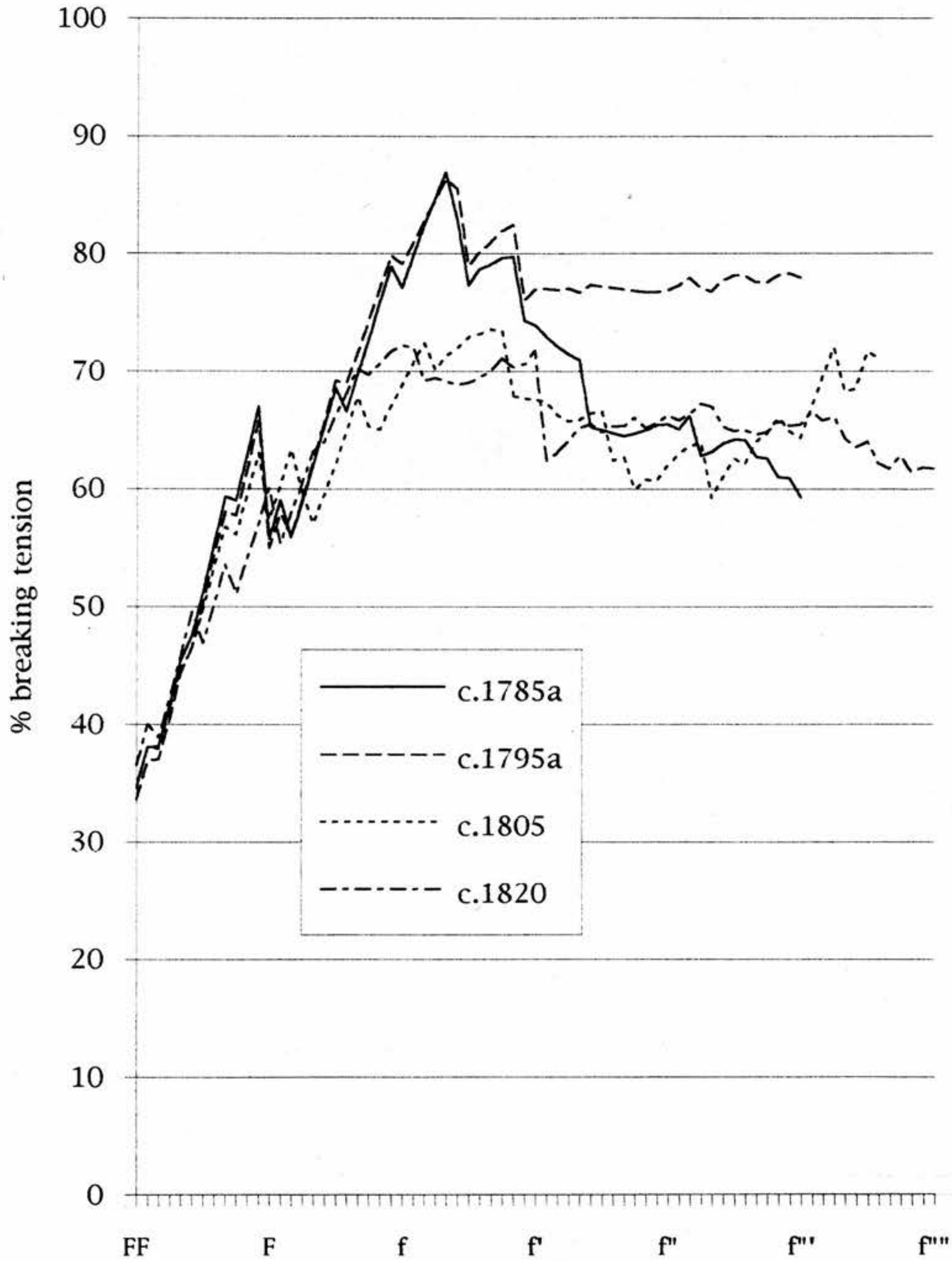
graph 80

The extent to which the strings are stressed in four grand pianos by Hofmann built at different periods

Graph 77 showed that in H/c.1800 the maximum proximity of the strings to breaking point was about 70%. Graph 81 compares the extent to which the strings are stressed in a further four pianos by Hofmann. These are H/c.1785a, H/c.1795a, H/c.1805 and H/c.1820. The first three of the latter instruments and H/c.1800 are assumed to have been strung with diameters conforming to Thomée's gauge equivalents for his Nuremberg system while H/c.1820 is assumed to have been strung with Huber's 'Berlin' sizes, both with the corresponding breaking tensions. All five instruments are assumed to be at a pitch of a' = 430 Hz.

The strings of the pianos by Hofmann dated c.1785 to c.1795 appear to be stressed to a maximum of about 85% whereas the strings of the pianos by him dated c.1800 and later are only stressed to a maximum of about 70%. While it must be emphasized again that no absolute significance can be attached to these figures because of the large number of assumptions on which they are based, we can conclude that the relative minimum safety margin for the strings with respect to breaking point appears to have been increased by more than a semitone. To put it simply, the earlier the instrument the closer the strings were to breaking point.

Four grand pianos by Ferdinand Hofmann
Proximity of the strings to breaking point
a' = 430Hz



graph 81

It should be noted that any improvement in the tensile strength of the wire Hofmann used during the period in which these instruments were made would have exaggerated the tendency for the strings of the later instruments to be further from breaking point than those of his earlier instruments, while any rise in pitch during the same period would obviously have taken the strings closer to breaking point.

Another difference between the earlier and later instruments shown in graph 81 is that in general, the earlier instruments have an area in the middle of the compass in which the strings are more highly stressed than in the extremes, while the strings of the later instruments are more evenly stressed throughout. To a lesser degree the same tendency can be observed in the instruments of Stein and Streicher. Graph 82 compares a piano by Stein of 1788 and one by the Streicher firm of 1826. The degree to which the iron strings are stressed is more even in the later instrument while the earlier one shows the peak in about the middle of the compass typical of the early Hofmann pianos. There is little doubt that the main reason for avoiding such peaks in the later pianos was to reduce the risk of breaking strings. In general we might even speculate that the heavier touch prevalent towards the end of Beethoven's life contributed to the necessity of reducing the degree to which the strings were stressed.

By 1839 the Streicher firm was building instruments with strings which, compared to those in the early instruments, were evenly stressed throughout the compass and which were stressed leaving a considerable safety margin. In order to calculate the proximity of the strings to breaking point of a piano built by the Streicher firm in 1839 (S/1839/3261) it was assumed that the gauge markings on the instrument originally referred to the gauges defined by the Streicher gauge caliper preserved in the Technisches Museum in Vienna.[256] This caliper was probably used by the Streicher firm from about 1835 onwards until at least 1860. The tensile strengths of four samples of wire (which also conformed in diameter to gauge diameters defined by the caliper) from a piano built by the Streicher firm in 1836 were measured. From them the breaking tensions of the iron gauges used on S/1839/3261 were calculated in the same way as the breaking tensions of the wire from the pianos by Hofmann (H/c.1800) and Graf ({c.1826/609}) were measured and used to calculate standard breaking tensions for the wire used in earlier pianos.

Graph 83 was made on the basis of the breaking tensions obtained for this later wire. A pitch of a' = 430Hz was again assumed. The strings are evenly stressed throughout the section of the compass strung in iron and are about two semitones further from breaking point in comparison with those on the 1826 instrument (compare graph 82).

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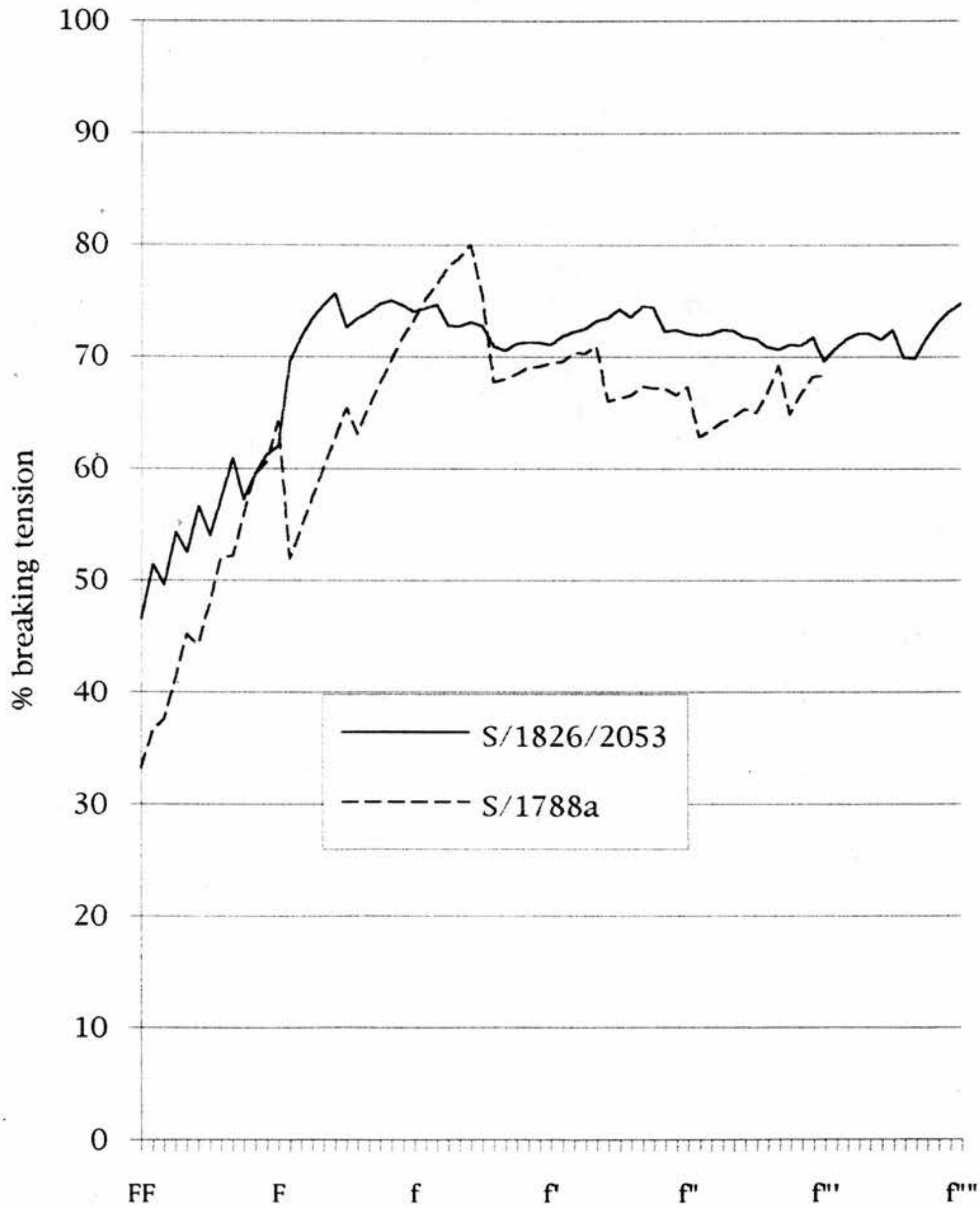
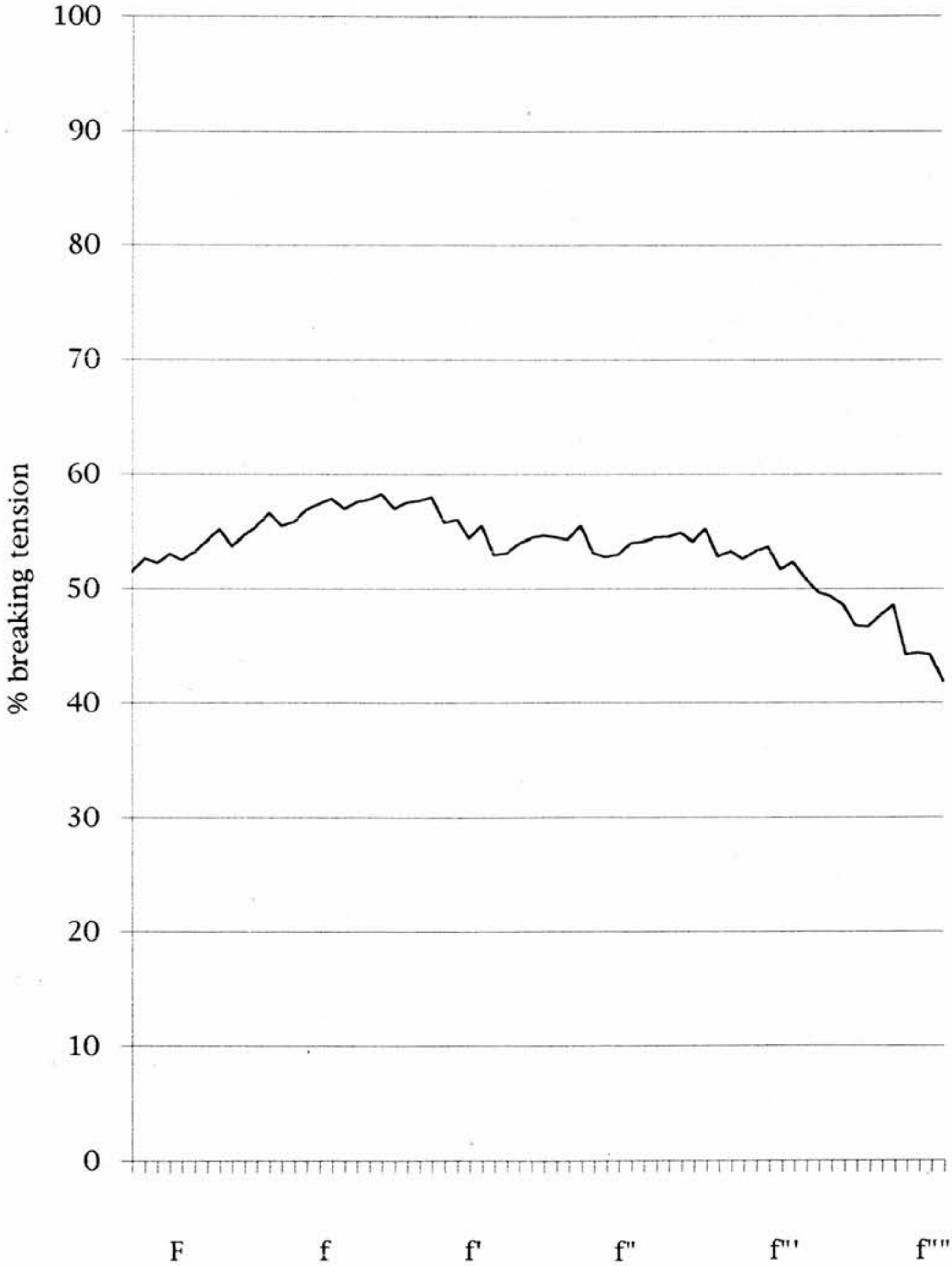
256 Alfons Huber, in 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 204, calls this system the Vienna system. For the mm equivalents see table 23 above. The Streicher firm was probably using this system before the caliper came into use, perhaps already in 1826.

Two pianos, one by the Streicher firm
(S/1826/2053)
and one by Stein (S/1788a)
Proximity of the strings to breaking point
a' = 430Hz



graph 82

Grand Piano Johann Baptiste Streicher
(S/1839/3261)
Proximity of the iron strings to breaking point
a' = 430Hz

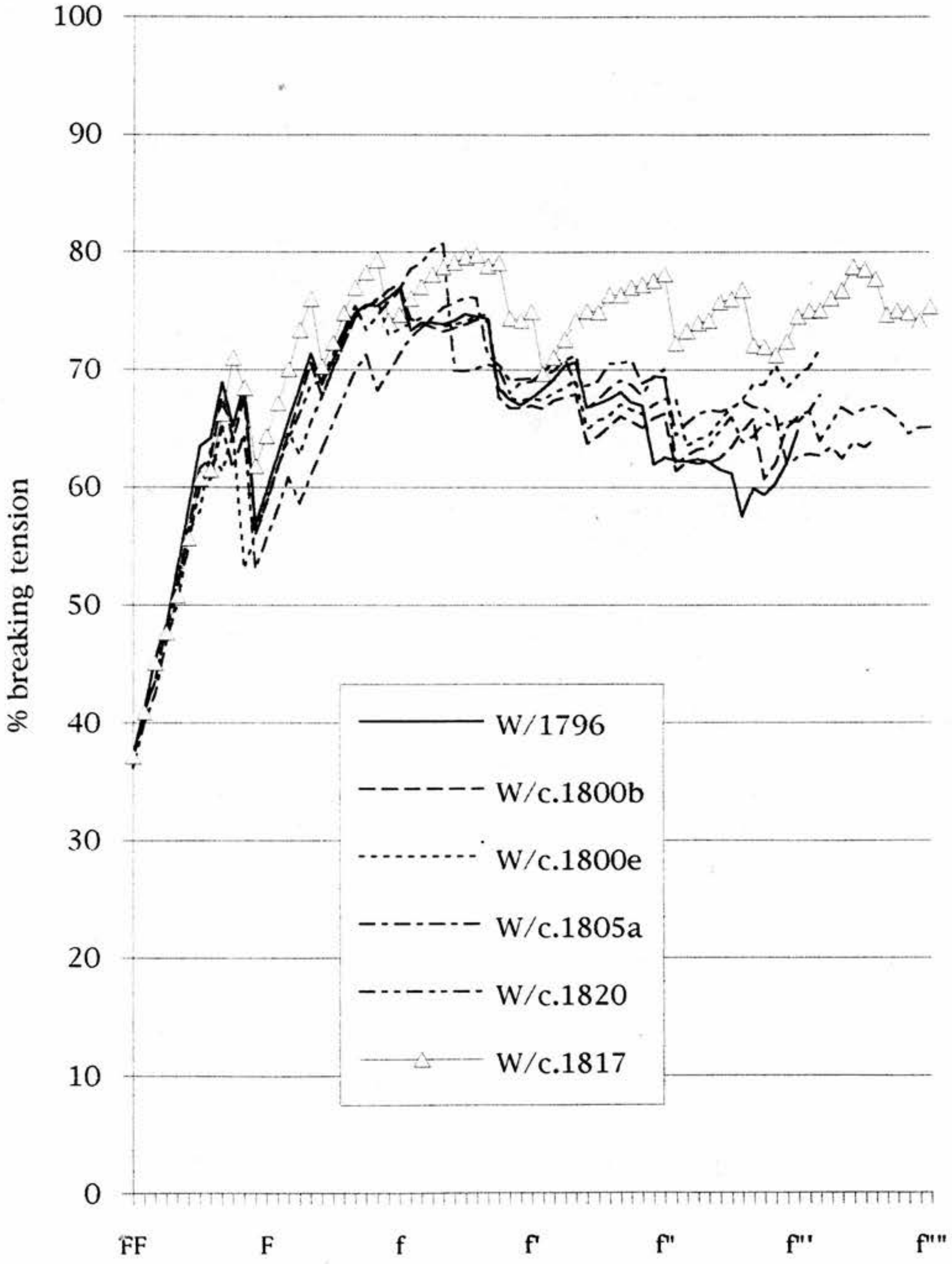


graph 83

Proximity of the strings to breaking point in the pianos of Walter

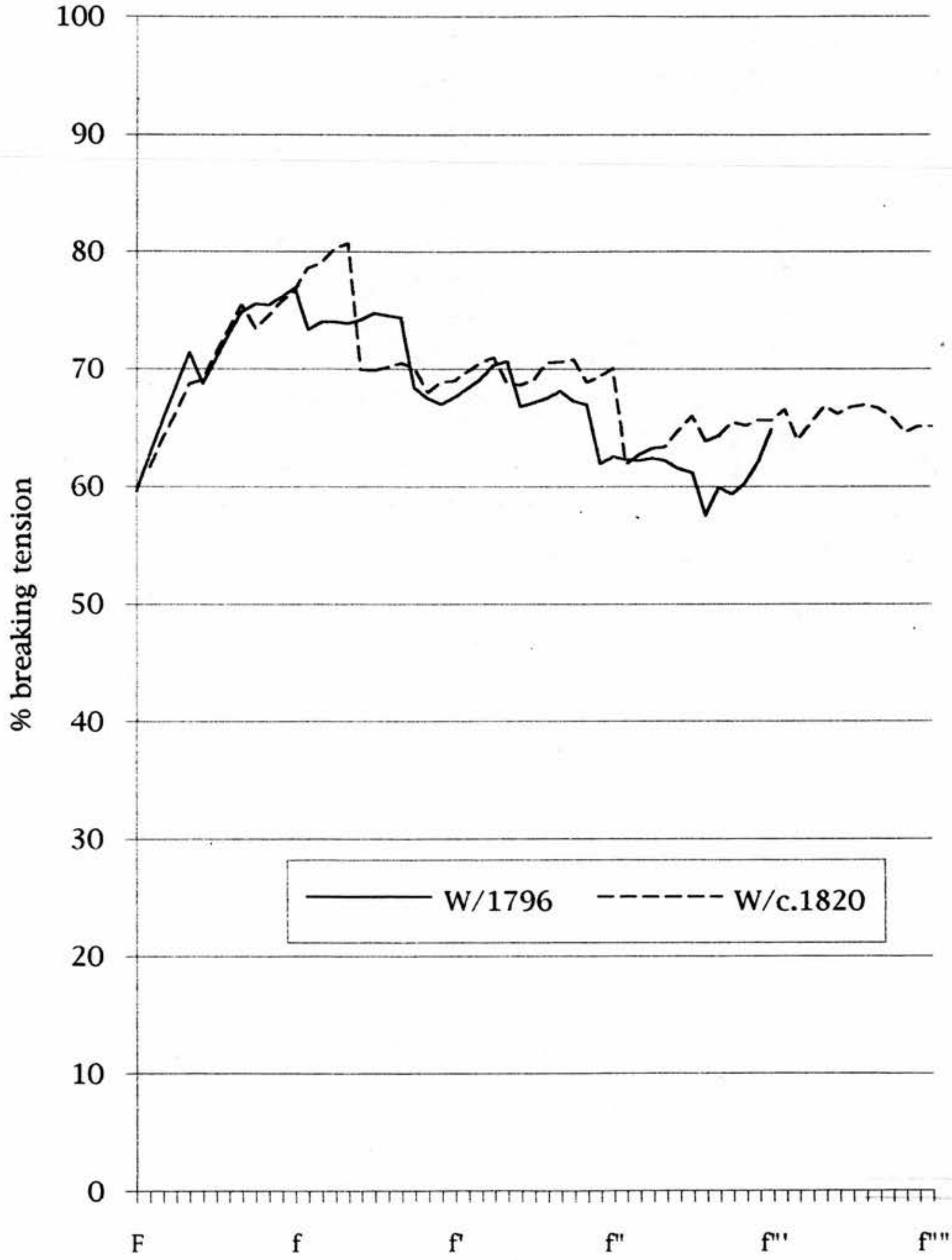
Despite apparently erratic variation in both the scaling design and the string thicknesses used in the pianos by Walter, the strings of the six instruments shown in graph 84 are evenly and consistently stressed in comparison with the strings of the pianos of Stein and of the earlier pianos of both Streicher and Hofmann. This consistency and evenness is also demonstrated by comparing the proximity to breaking point of the iron strings of two pianos by Walter, one of 1796, the other of c.1820. In keeping with the general trend observed in the pianos of most makers, the c.1820 piano has much thicker and shorter strings than the 1796 piano. The 1796 instrument, for instance, has a c" string length of 287mm while that of the c.1820 instrument is 270mm. The c" string of the 1796 instrument is marked for gauge 2 (in Thomée's Nuremberg system 0.47mm) while the c" for the c.1820 instrument is marked for $3/0^{1}/_{2}$ (in Huber's 'Berlin' system 0.68mm). Yet the strings in the two instruments are stressed to almost exactly the same degree (graph 85).

Six pianos by Anton Walter
Proximity of the strings to breaking point
a' = 430Hz



graph 84

Two pianos by Anton Walter
Proximity of the iron strings to breaking point



graph 85

The divided bridge and the changeover from brass to iron

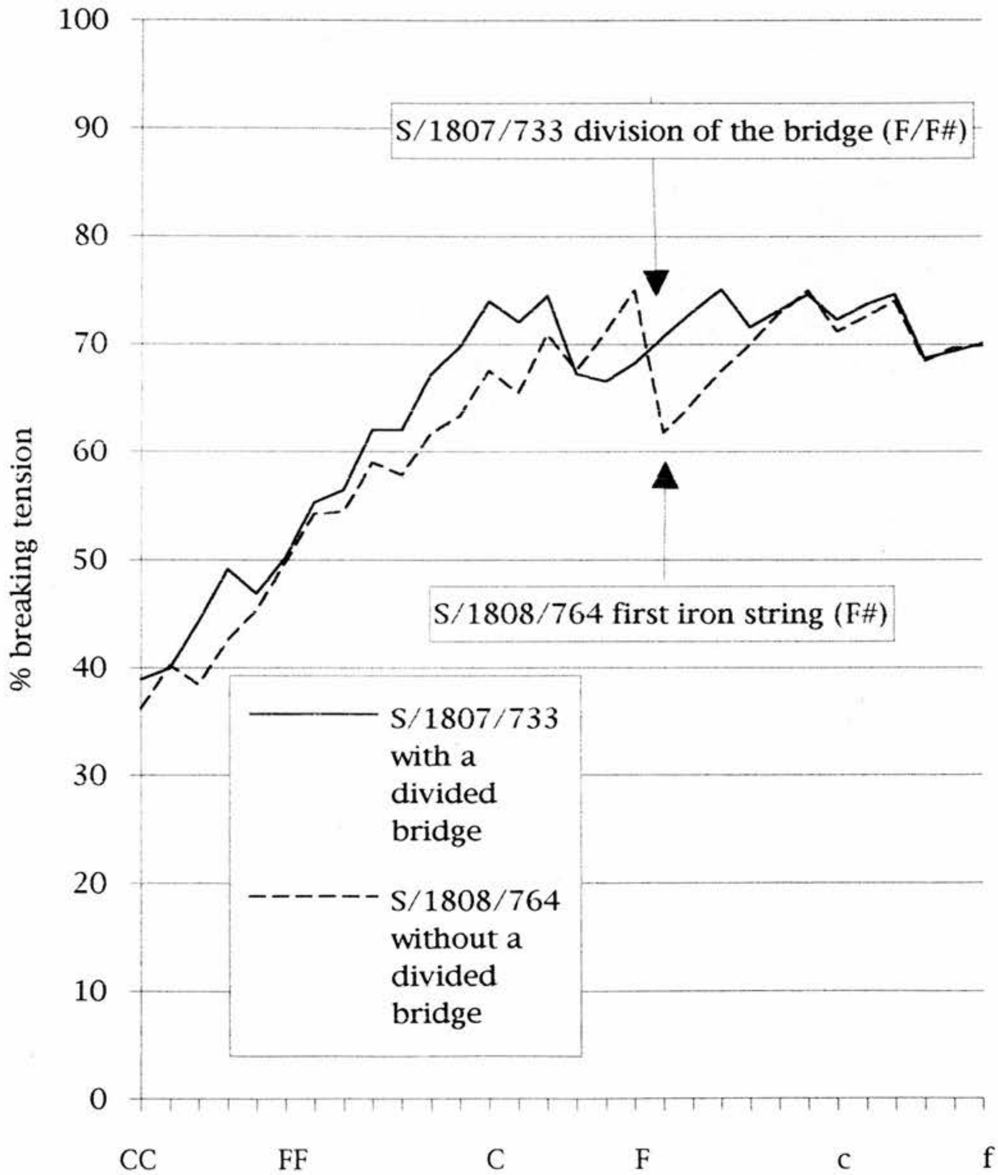
The effect of the introduction of the divided bridge on the evenness with which the strings are stressed at the changeover from brass to iron is illustrated in graph 86. In S/1807/733, with a divided bridge, there is a smooth transition from the brass to the iron strings in the extent to which the strings are stressed even though there is a sharp increase in tension. In S/1808/764, without the divided bridge, there is an abrupt drop in the extent to which the first iron strings are stressed in comparison with the last brass strings while there is obviously no discontinuity in the tension curve. But the advantage of evenly stressing the strings at the changeover from brass to iron cannot initially have been of much importance to Streicher. If it had been, she would not have returned to a single bridge only a few months after starting to use it. The same is true of both Schantz and Fritz, the only other two Viennese builders who used the divided bridge before 1820. All three used the divided bridge early in their careers and then returned to the single bridge. The disadvantage of the stiffness added to the soundboard by having two parallel bridges at the changeover from brass to iron may have outweighed the advantage of having the strings evenly stressed.

For harpsichords strung in brass and iron it is generally accepted that the brass is taken as high as possible before the changeover to iron is made. This appears to be the case with the harpsichord in Stein's *vis-à-vis* instrument of 1777 where the changeover to iron is made at the point at which the brass is stressed to about the same degree as the maximum to which the iron strings are stressed (graph 87). Apparently, Stein took the brass as high as he could while still maintaining the same safety margin to which he kept for the iron strings. Based on the assumptions regarding pitch, string diameters and standard breaking tensions used here that safety margin was about 70% or three semitones.

The piano of the *vis-à-vis* instrument presents a different picture. At the changeover, the differential in the stress level appears to have been minimalised. The highest brass strings are not stressed to the maximum of 70% reached in the iron-strung section at g#'. Incidentally, as soon as that maximum is reached at g#' there is a gauge change to a thinner (and therefore stronger) gauge. At g#" the maximum is again reached and again there is a change to a thinner gauge (graph 87).

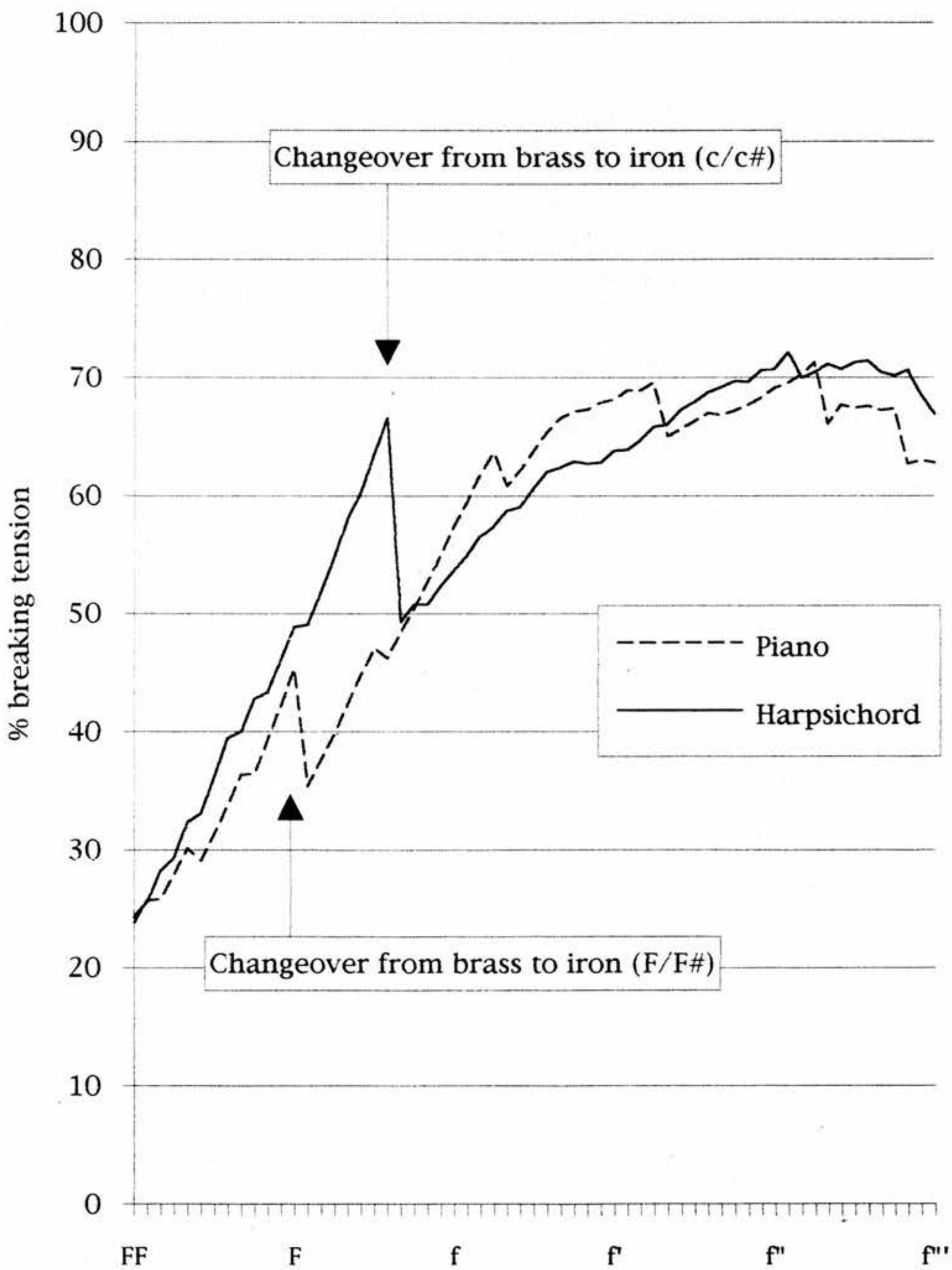
The changeover from brass to iron appears to have been arranged in a similar way in the earlier pianos by Hofmann. At the changeover in H/c.1800, for instance, the brass strings are only stressed to about 60% whereas a maximum of about 80% is reached in the iron-strung section (graph 88). But if the brass had been taken higher the stress differential at the changeover would have been greater. In Hofmann's later instruments the brass strings are also not stressed to the maximum reached by the iron strings and again the stress differential at the changeover is reduced to a minimum (graph 89). But the difference between the maximum stress in the brass strings and the maximum stress in the iron strings is less than in the earlier instruments.

Two pianos by Streicher
One with a divided bridge (S/1807/733) and one without (S/1808/764)
Proximity of the strings to breaking point around the changeover from brass to iron strings



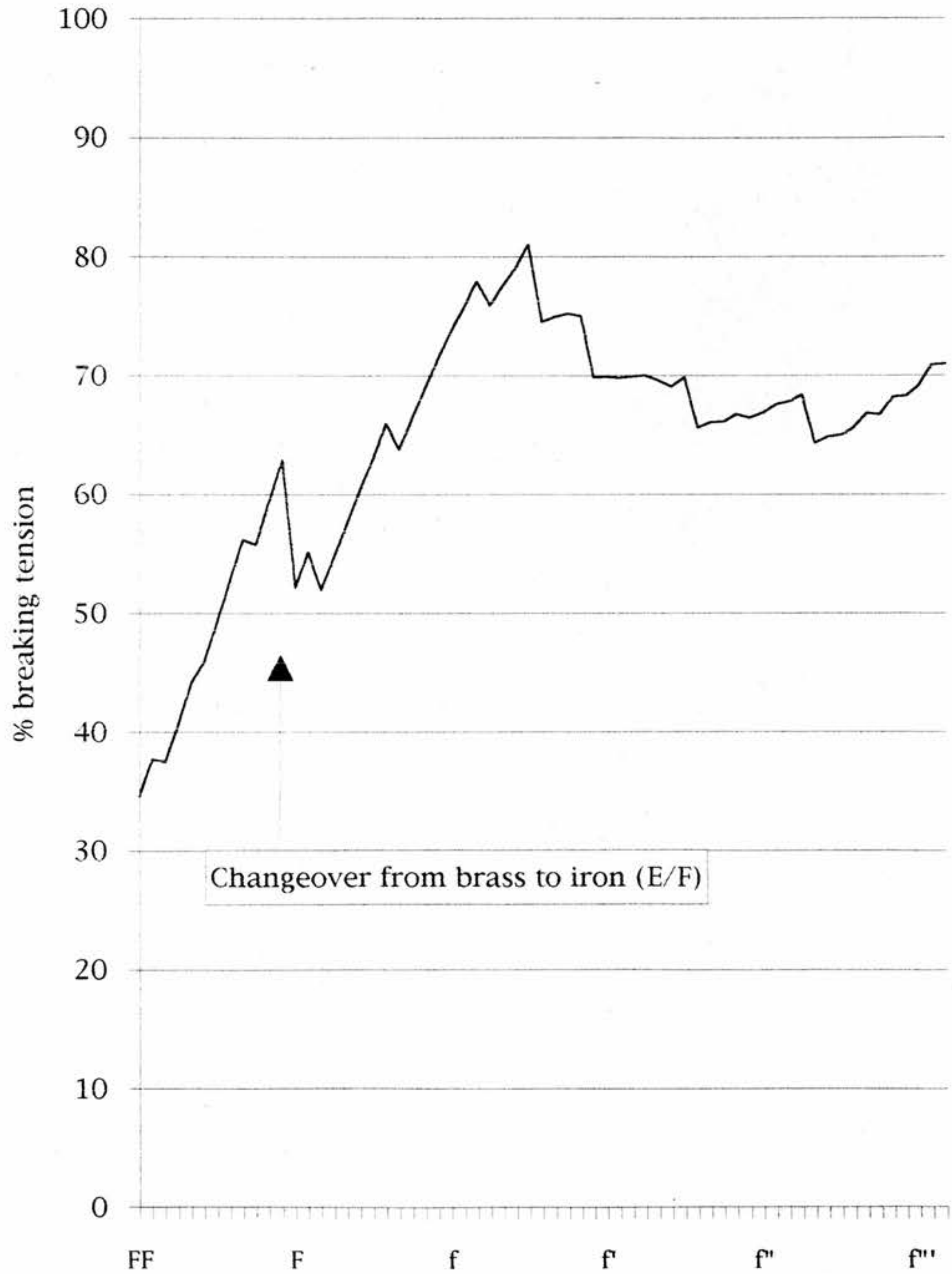
graph 86

The vis-à-vis instrument (S/1777) by Stein
Proximity of the strings to breaking point
a' = 430Hz



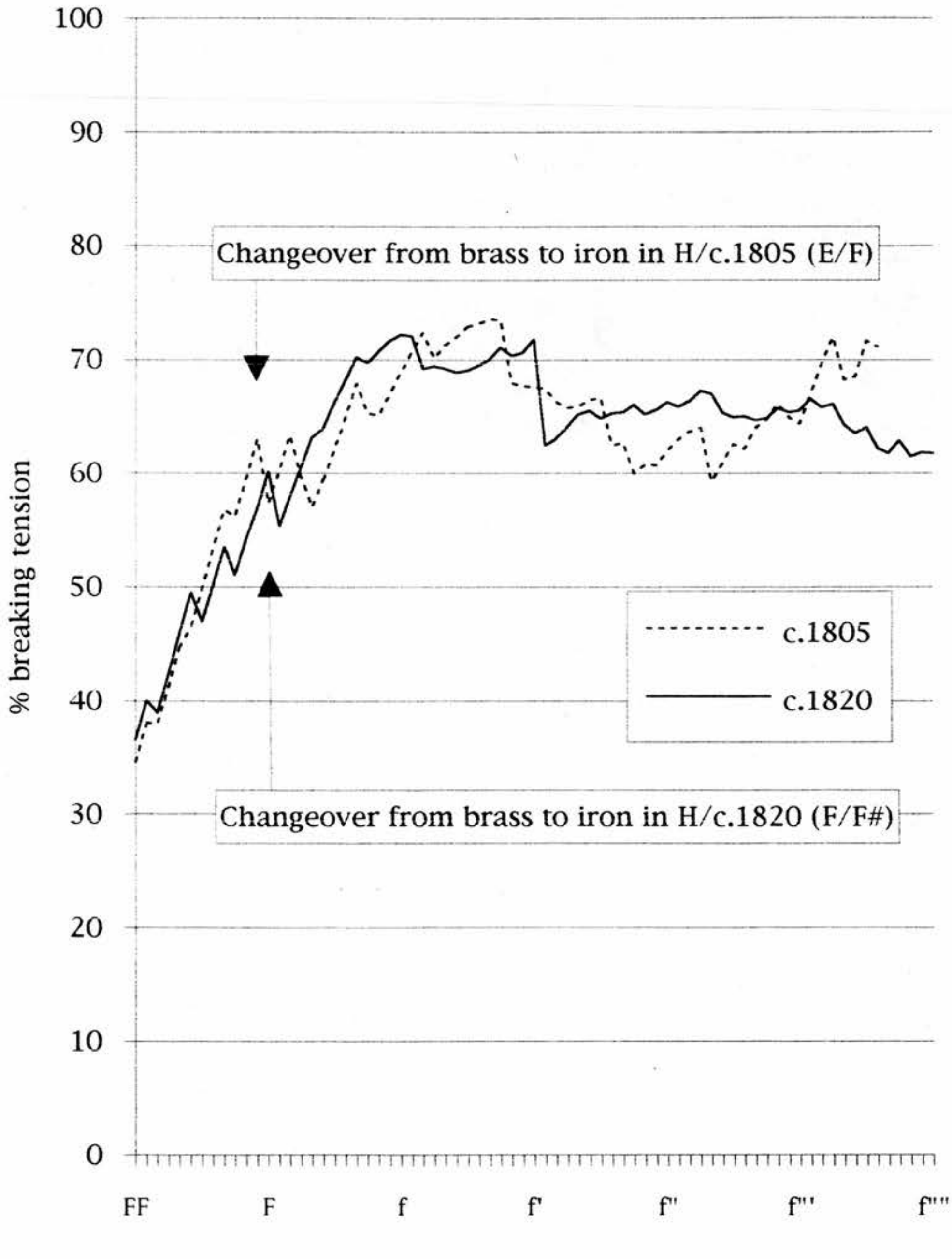
graph 87

Grand Piano Ferdinand Hofmann (H/c.1800)
Proximity of the strings to breaking point
a' = 430Hz



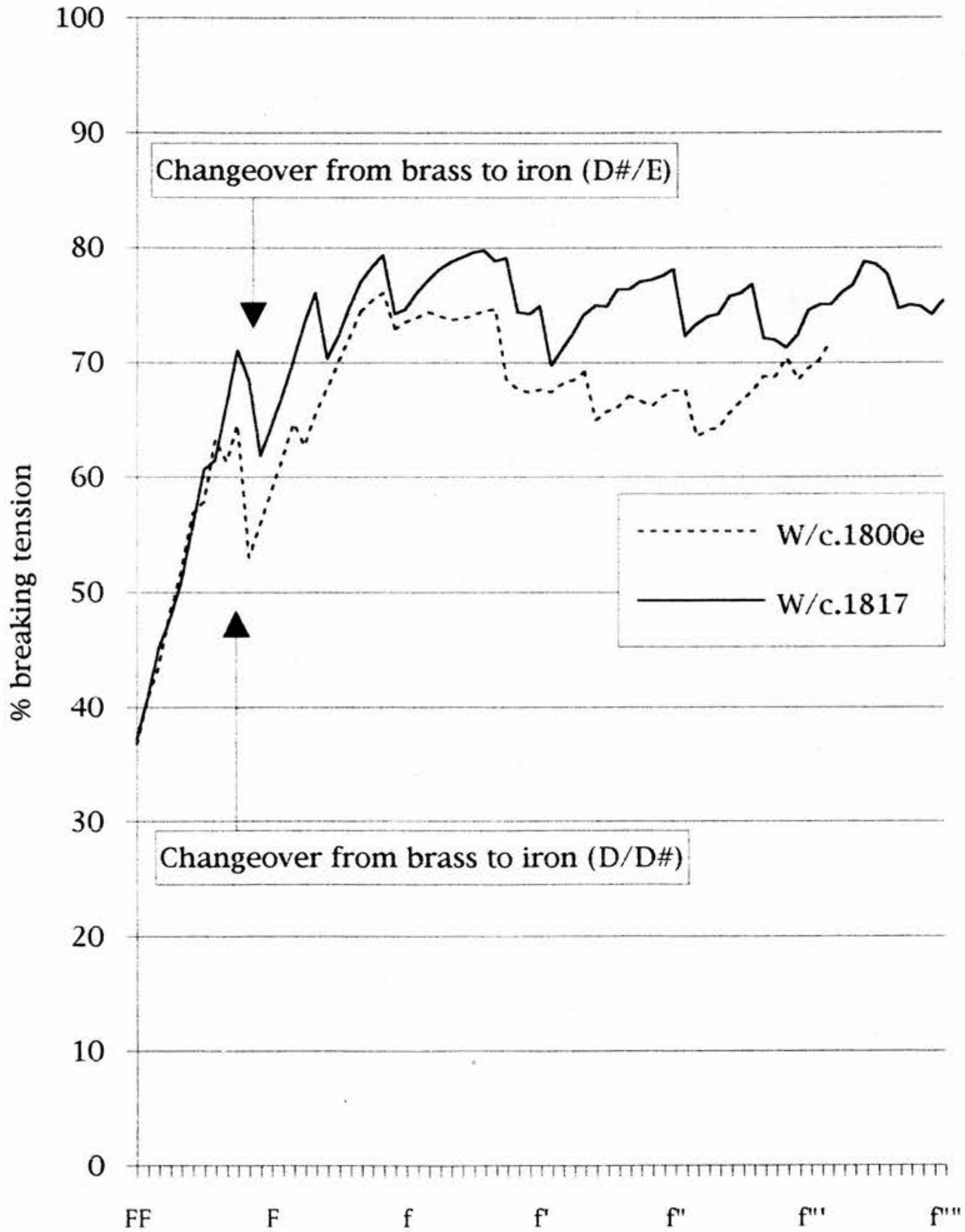
graph 88

Two pianos by Ferdinand Hofmann (H/c.1805 and H/c.1820)
Proximity of the strings to breaking point
a' = 430Hz



graph 89

Two pianos by Anton Walter
(W/c.1800e and W/c.1817)
Proximity of the strings to breaking point
a' = 430Hz

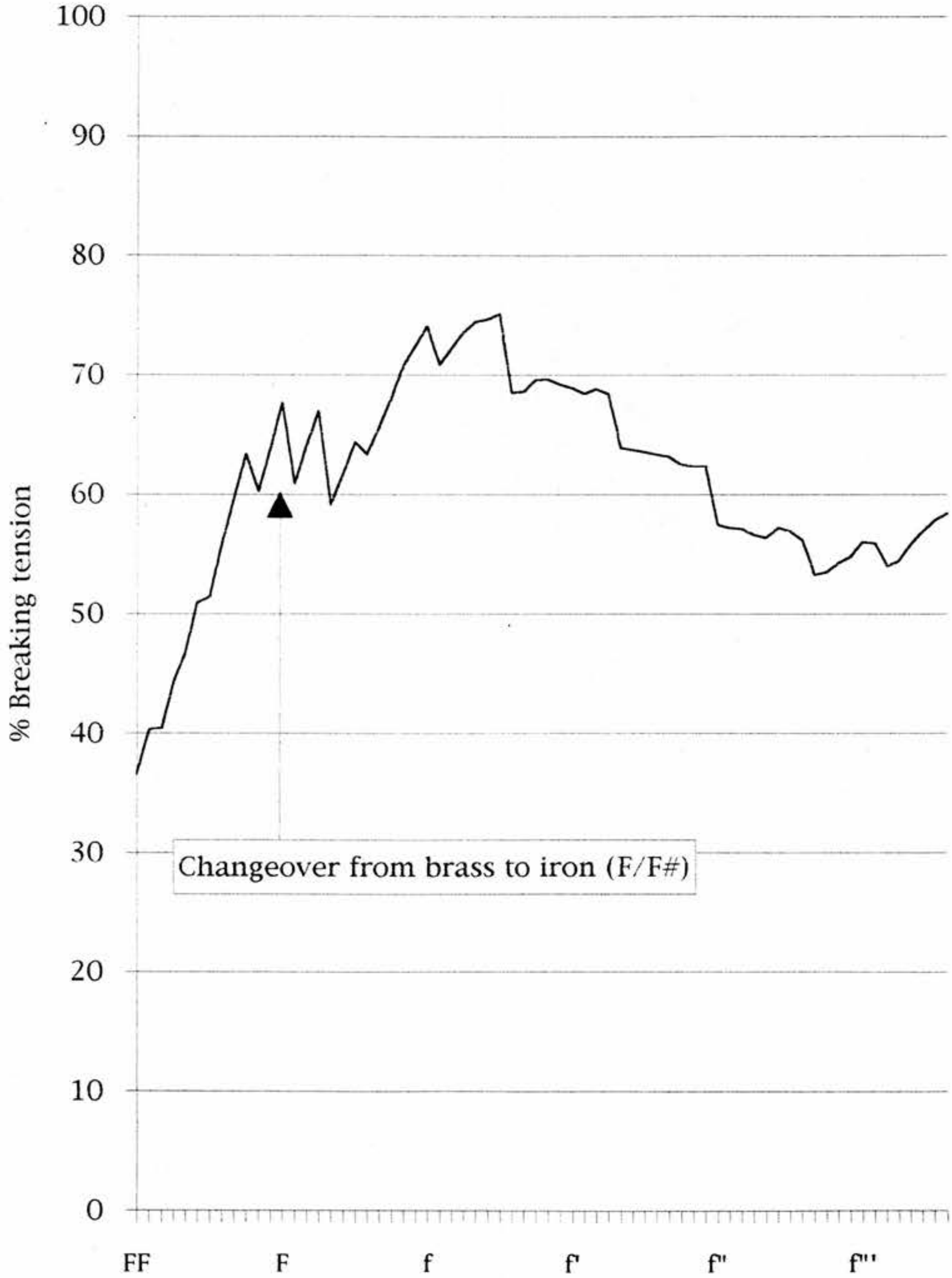


graph 90

Walter also appears to have minimised the stress differential at the changeover from brass to iron (graph 90). He too does not appear to have taken the brass as high as he might have done. The maximum stress reached by the iron strings is about 10% greater than in the highest brass strings.

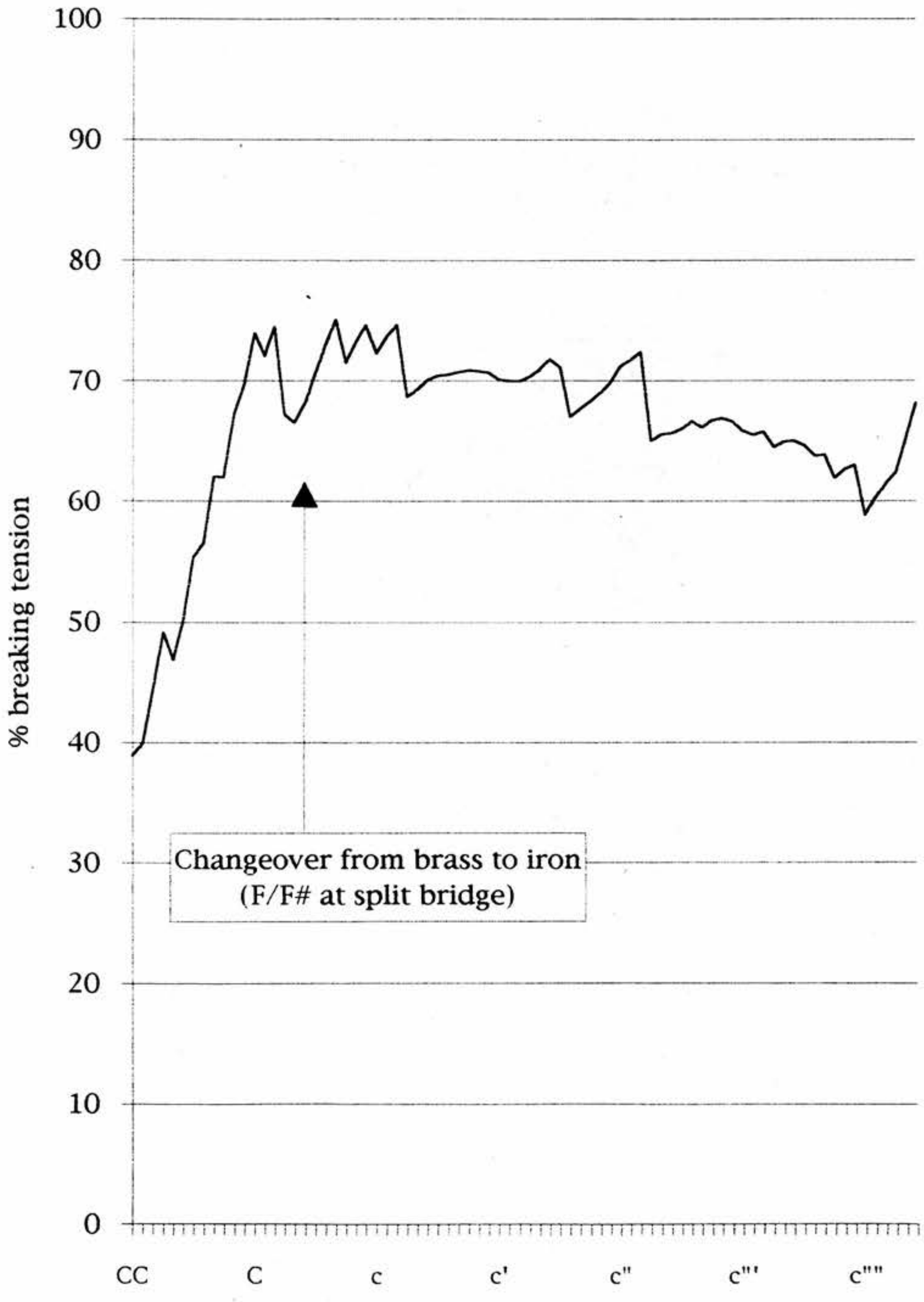
In the following six graphs the proximity of the strings to breaking point are shown for a chronological series of pianos by the Streicher firm dated c.1804, 1807, 1811, 1819, 1823 and 1830. In none of these instruments is the highest brass string stressed to the same maximum as the iron. Whether there is a divided bridge or not, Streicher appears to have tolerated a maximum stress of between 70% and 75% (on the assumptions made here) usually reached in the tenor. In the extreme bass the brass strings are under-stressed at about 40% of breaking tension. Between the bottom note and the tenor there is a steady rise in the degree to which the strings are stressed and includes a more-or-less smooth transition from brass to iron. In some instruments, most notably S/1830/2383, the changes to thinner gauges from the middle of the compass upwards appear to have been made in order not to exceed a maximum stress of about 70%.

Grand piano Nannette Streicher (S/c.1804a)
Proximity of the strings to breaking point
a' = 430Hz



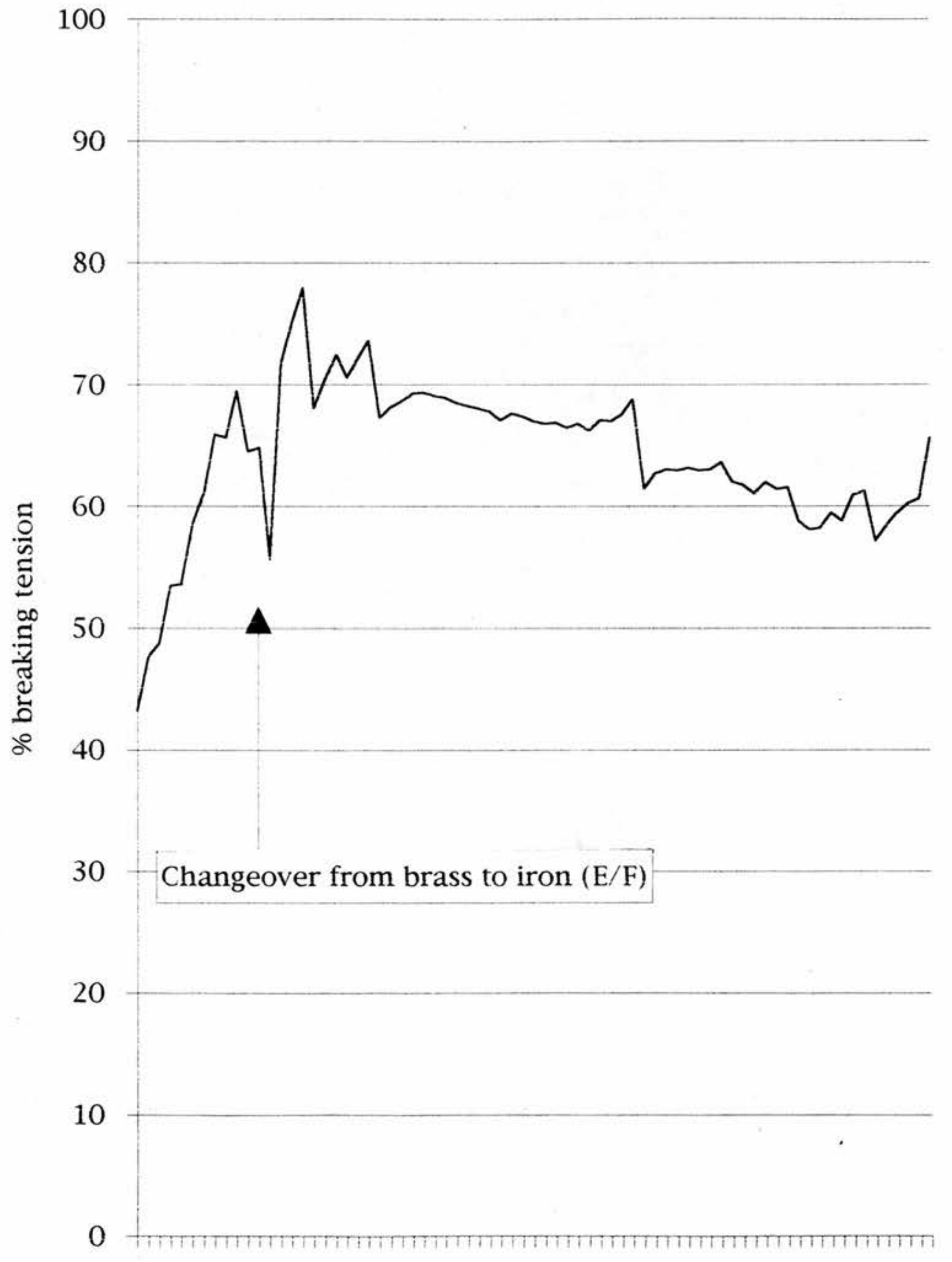
graph 91

Grand piano Nannette Streicher (S/1807/733)
Proximity of the strings to breaking point



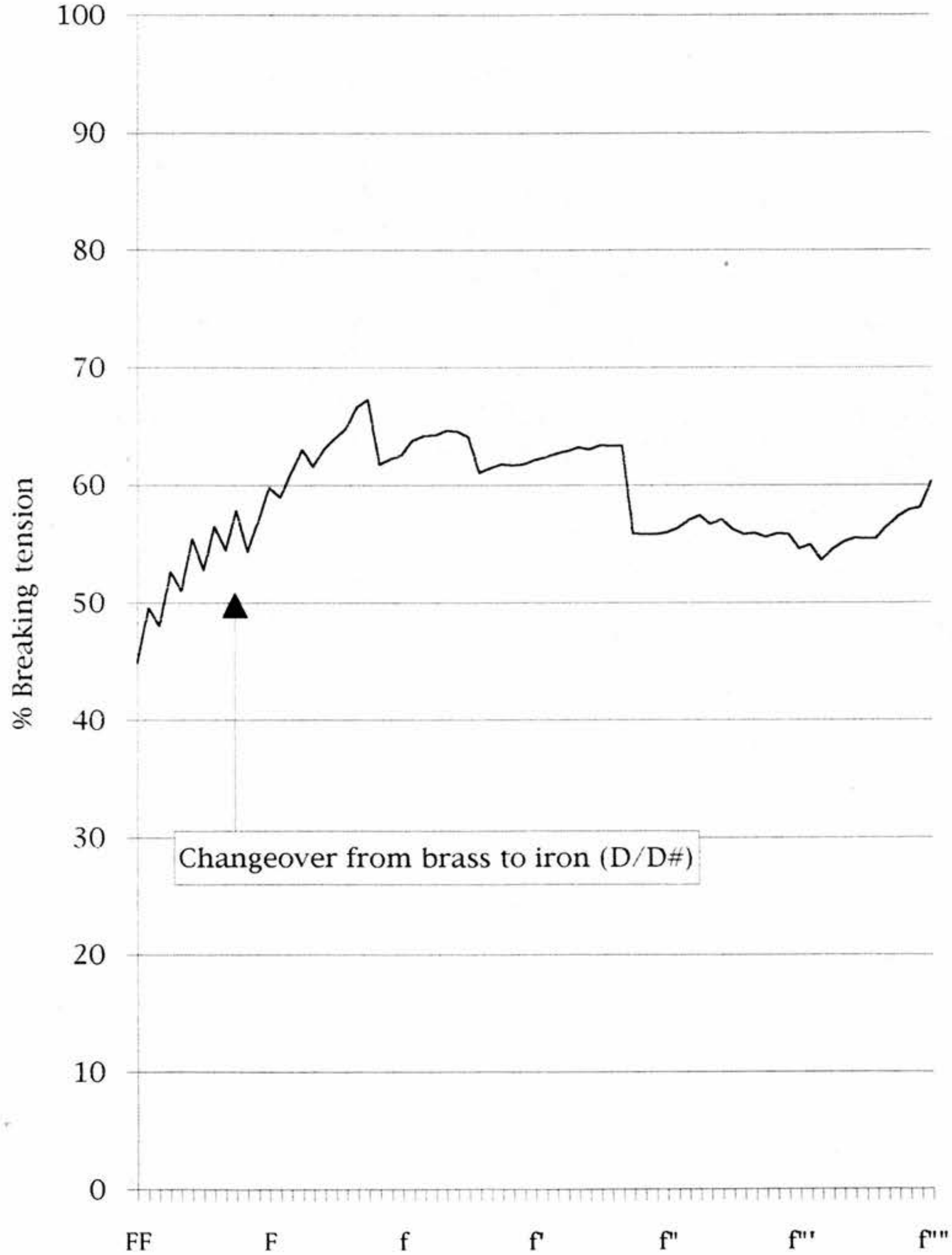
graph 92

Grand piano Nannette Streicher S/1811/908
Proximity of the strings to breaking point



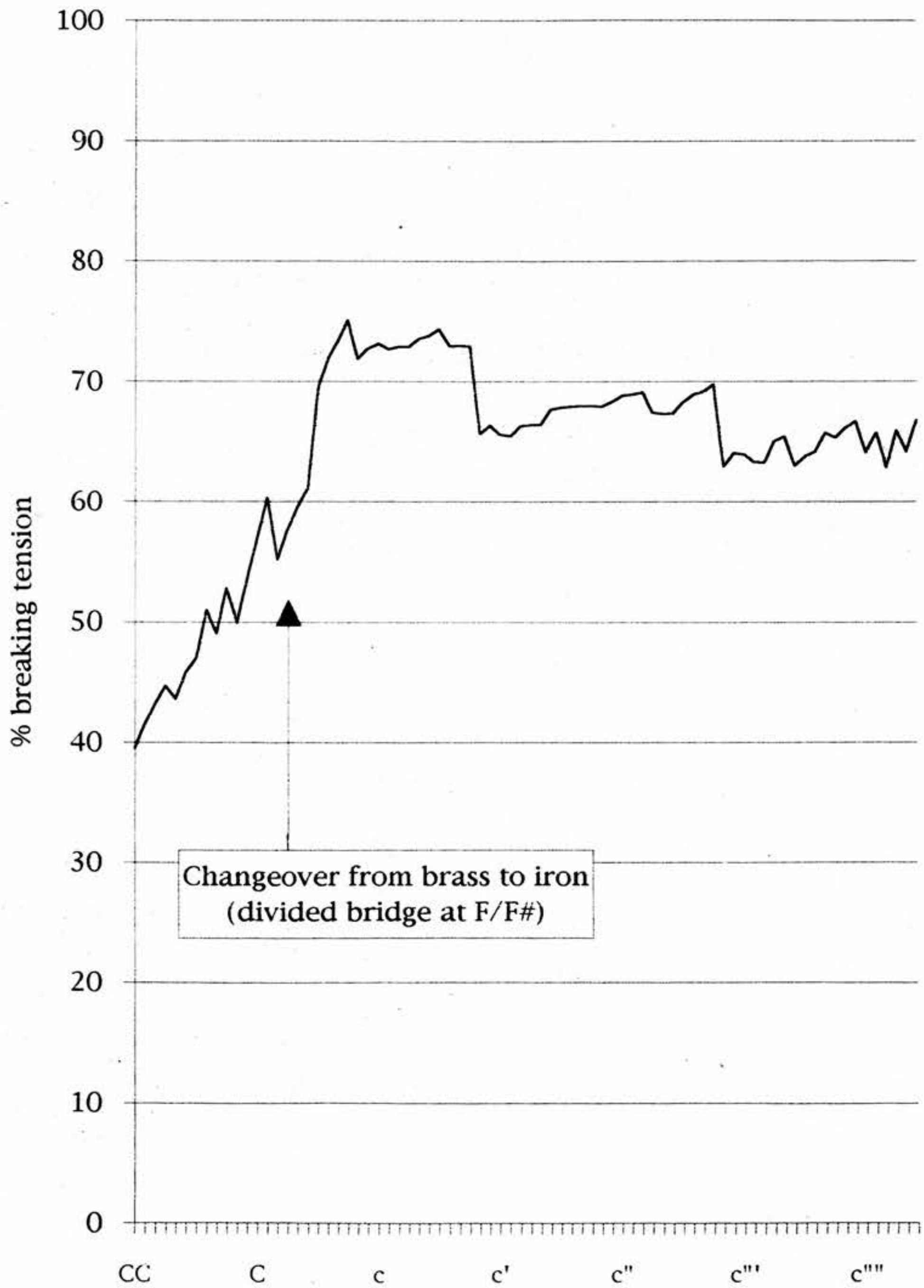
graph 93

Grand Piano Nannette Streicher S/1819/1415
Proximity of the strings to breaking point
a' = 430Hz



graph 94

Grand piano Nannette Streicher (S/1823/1756)
Proximity of the strings to breaking point



graph 95

Grand piano Nannette Streicher (S/1830/2383)
Proximity of the strings to breaking point
a' = 430Hz

graph 96

The closer a sounding string is to breaking point the better the harmonics are in tune with the fundamental.[257] This may be the reason why the changeover from brass to iron is made as high as possible in harpsichords and may lie behind the belief that a string sounds best when critically stressed. In an essay written in C. F. Cramer's *Magazin der Musik* in 1784, the author ('J. B. v. H.') states that

> 'Of all the notes which a string offers at different tensions, the one which realises the most beauty to the ear is that produced by the string at the highest degree of tension which it can take.'[258]

J. R. Erhard, in his announcement for a new string gauge system in 1793 makes the same point:

> 'In the way, until now normal, in which strings for clavichords, pianos etc., were made one has been satisfied with using the same strings for five or more semitones. In doing this one pays too little attention to the relationship between the strings and the sound. Strings which are under too much tension break while those under a lesser tension make an unpleasant sound. This problem, together with the

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257 See Grant O'Brien, *Ruckers, A harpsichord and virginal building tradition*, Cambridge 1990, 18-9.

258 '*Unter allen Tönen, welche eine Saite unter verschiedenen Spannungen angiebt, gewährt derjenige dem Gehör den mehrsten Reiz, welchen sie bei dem höchsten Grad der Spannung, den sie auszuhalten im Stande ist, hervorbringt.*' J. B. v. H., 'Beitrag zu einer allgemeinen Verbesserung der Claviere, aus mechanischen Gründen hergeleitet', *Magazin der Musik*, ed. Carl Friedrich Cramer, Hamburg 1784, 277-298.

inconvenience of having the spools of string inscribed with numbers, has brought me to the conclusion to resolve both these problems. To this end I made several experiments to find out which strings give the best sound for the notes for which they are intended.'[259]

While the scaling of harpsichords may be designed to ensure that the strings are critically stressed this is clearly not the case with the pianos built in the Viennese and southern German traditions. In general the makers appear to have designed their scalings and selected their string gauges such that there is a smooth transition from brass to iron, not in terms of absolute tension but in terms of the proximity of the strings to breaking point.

Two tendencies also emerge. One of these is the tendency to increase the margin of safety, that is to design instruments with the strings continually further from breaking point. This may reflect the increasingly heavy touch used in the relevant period but may also have to do with the need to provide pianos which could be tuned down or up to meet the varied pitch requirements of the day. The other tendency which emerges is the tendency to equalise not the absolute tension throughout the compass but again

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259 '*Die bisher gewöhnliche Art, Saiten für Klaviere, Fortepiano etc. zu ferfertigen, da man sich begnügte, für 5 und mehrere Sekundenintervallen die nemliche Saite zu bestimmen, die, weil man auf das Verhältniß der Saiten und Töne wenig Rücksicht nahm, bey einer geringern einen unangenehmen Klang von sich geben mußte, - und die Unbequemlichkeit der mit* Nummern *bezeichneten Saitenrollen, hat mich zu dem Entschluß gebracht, beiden Mängeln abzuhelfen.' Intelligenzblatt der allgemeinen Literaturzeitung Nr. 93*, 1793, 743. Quoted in Remy Gug, 'En remontant la filière de Thoiry à Nuremberg', *Musique Ancienne*, 18, 1984, 69 and Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, 200.

the proximity of the strings to breaking point. This may reflect a tendency to design instruments with an even tone quality throughout the compass, away from the idea of a variation in tone quality, of different 'registers' in different areas of the compass. Stein and Hofmann in his earlier instruments appear to have varied the proximity of the strings to breaking point and had the strings maximally stressed in the middle of the compass. Walter and Streicher appear to have striven after equally stressed strings throughout the compass.

CHAPTER IIX

PITCH

String lengths and pitch

For a given string material and tension, the pitch of a sounding string is defined by its length. Other things being equal, the pitch of a string is inversely proportional to its length so that the scaling of an instrument serves as an indicator of the intended relative pitch, a principle often used in the literature on the harpsichord.[260] It follows, for instance, that two harpsichords, one of which has strings half the length of those of the other, will be pitched an octave apart. Working on the same principle Grant O'Brien has shown that the Ruckers dynasty not only built families of harpsichords, spinets and muselars at pitches an octave, a fifth and a fourth apart but also that they made instruments belonging to two such families separated in pitch by a whole tone.[261]

But besides string material, length, diameter and tension the later piano builders had to take the principle of tensile pick-up (or rather its converse) into account when designing their instruments. In order to obtain more volume increasingly thicker strings were

260 See for instance Grant O'Brien, *Ruckers, A harpsichord and virginal building tradition*, Cambridge 1990, 56-60.

261 See Grant O'Brien, *Ruckers, A harpsichord and virginal building tradition*, Cambridge 1990, 223-4.

used. Because thicker strings are relatively weak compared to thinner strings (the converse of tensile pick-up) the scalings had to be shortened in order to avoid strings breaking. Other things are thus not equal, at least for pianos, and the inverse relation between string length and pitch no longer holds true. Two pianos, intended to be tuned to the same pitch can have different scalings. The one has long thin strings, the other short thick strings.

Up until about 1820, however, when the process of improving the tensile strength of wire appears to have begun in earnest, the piano makers discussed here did design their instruments with continually shorter strings, and during the same period pitch did tend to rise.[262] But the extent to which the strings were shortened was far greater than necessary to take account of the rise in pitch.

The following observations emphasize that there is no direct or exclusive relation between the shortening of string lengths and the rise in pitch during the period between about 1780 and 1820 in the southern German and Viennese piano building traditions. The c" string length for a piano by Hofmann of about 1784 is 309mm and for one of about 1820 270mm.[263] This difference is equivalent to a difference in pitch of more than a whole tone.[264]

262 The string lengths in the English tradition cannot be said to follow the same pattern. To give some examples of the c" lengths (mm) of grand pianos (all dated) by the Broadwood firm: 1787, 270; 1792, 279; 1793, 278; 1794, 278; 1796, 277; 1799, 274; 1805, 278; 1810, 274, 1815, 271; 1822, 280; 1824, 278; 1827, 277; 1832, 279. My thanks to David Hunt and Edwin Beunk for five of these measurements. The others are my own.

263 H/c.1784a and H/c.1820.

264 234 cents.

Similarly, the c" string length for a piano by Stein of 1782 is 299mm while for an instrument by Nannette Streicher of 1820 the c" string length is 267mm, again a difference equivalent to a rise in pitch of a whole tone.[265] Pitch rose in Vienna between 1785 and 1820 but by less than a semitone.[266] Although any increase in pitch would have contributed to the necessity of shortening strings, the main reason lay in the use of thicker and therefore relatively weaker strings.

That scaling and pitch were not exclusively related to each other is also illustrated by the difference in the scalings used by different makers at one period. Two pianos by Könnicke, for instance, both dated 1796, have c" string lengths of 290mm and 294mm, lengths that Stein was using about ten years earlier, while the c.1796 piano by the Geschwister Stein has a c" string length of 282mm.[267] A piano by Streicher of 1805 has a c" string length of 291mm and two six-octave pianos of about 1805 by Rosenberger have similar scalings with c" string lengths of 293mm and 292mm. But a piano by Schantz, also of about 1805, has a c" string length of 285mm and a piano by Hofmann of about the same date has an

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265 S/1782 and S/1820/1486. The difference is equivalent to 196 cents.

266 According to Bruce Haynes (personal communication 1995), the evidence from woodwind instruments of the period indicates that pitch rose in Vienna from about a' = 435 Hz in as early as 1770 to a' = 445 Hz by about 1820. This does not even amount to a semitone (39 cents).

267 K/3, 1796, c" 290mm; K/4, 1796, c" 294mm; (S/1784, 1784, c" 295mm). S/c.1796/27, c.1796, 282mm. The difference between a c" string length of 294mm and 282mm is equivalent to a pitch difference of 72 cents.

even shorter c" string length at 277mm.[268]

The various builders chose different string thicknesses for their instruments, probably depending on their taste for volume and tone quality, and hence different string lengths. There is little doubt too that the makers also made different choices with regard to the proximity of the strings to breaking point. Their preferences in this latter respect may have been guided by tone colour but must have been limited by the quality of the wire they used. At one extreme, the longest scaling would indicate a reliance on better quality wire and a preference for thin strings stressed to a maximum. At the other extreme, the shortest scaling would indicate a lack of faith in the quality of the wire and a preference for thick strings, under-stressed to allow a wide margin of safety. At any one time these two extremes and all the variations between them would have resulted in a variety of scalings for pianos. Yet all these instruments were presumably intended to be used at about the same pitch. Scaling, broadly speaking, is no indication of pitch.

But as we shall see, there are some special cases in which pianos were made concurrently, by individual builders, with different scalings suggesting that they were nonetheless intended for different pitches.

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268 Rosenberger: {Milan} and {Italy}. I am again grateful to Stefano Strufaldi for bringing {Italy} to my attention. Streicher: S/1805/649; Schantz: Sz/7; Hofmann: H/c.1805.

Choir pitch and chamber pitch

There are several references to two different contemporaneous pitches, called *Chorton* and *Kammerton*, or choir pitch and chamber pitch, in the relevant literature of the late eighteenth and early nineteenth century. These two pitches are historically described as fixed at more or less a tone apart in the late eighteenth century, if not earlier. One of these descriptions is in J. N. Forkel's *Musikalischer Almanach für Deutschland* of 1782, published in Leipzig. Forkel describes a new type of piano, invented in Berlin by a certain Hofrath Bauer, with a transposition device so that

> '... if the wind instruments are one or two tones higher than the chamber pitch, one can slide the keyboard in an instant so that the pitches are matched.'[269]

C. L. Röllig's booklet of 1795, published in Vienna, describing his new invention, the *Orphica*, a small portable piano, contains the clearest reference to choir pitch in relation to the piano:

> '.... because the tuning [of the *Orphica*] is in choir pitch, that is about one tone higher than is usual in the orchestra....'[270]

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269 '[...] *wenn dabey die blasenden Instrumente um einen oder zween Töne höher sind, als der Kammerton, so kann man das Klavier in einem Augenblicke schieben, und dadurch den Ton desselben mit jenem gleichstimmig machen.*' Johann Nicolaus Forkel, *Musikalischer Almanach für Deutschland auf das Jahr 1782*, Leipzig 1782, 19.

270 '*Da aber die Stimmung im Chortone, das ist: um einen Ton höher, als bey dem gewöhnlichen Orchester stehet,...*' C. L. Röllig, *Orphica. Ein musikalisches Instrument. Erfunden von C. L. Röllig*, Vienna 1795, 10-11.

Only seven years later, in Koch's *Musikalisches Lexicon* of 1802, *Chorton* is described as belonging to the past. It was

> 'That pitch which formerly prevailed in organs and was one tone higher than the now normal pitch, which one calls the chamber pitch.[...] This lower pitch became dominant more and more, [...] and now one also uses it for church music.'

Koch adds a footnote referring to a third, higher pitch:

> 'Sometimes there is also one a minor third higher, only found, however, in very old organs.'[271]

In his handbook of 1804 Nachersberg confusingly describes choir pitch as a whole tone lower than chamber pitch, probably a slip of the pen. Gall, in his unacknowledged publication of Nachersberg's work repeats the same mistake:

> 'Concerning the pitch to which one should tune the instrument, one should realise that the chamber pitch is a whole tone higher than chapel pitch, called choir pitch in Germany, and that the latter is usual in the churches.'[272]

271 '*Derjenige Stimmton, welcher ehedem durch die Orgelen veranlaßt wurde, und einen Ton höher ist, als der jetzt gewöhnliche Stimmton, den man den Kamerton nennt* [...] *Nach und nach wurde diese tiefere Stimmung die herrschende,* [...] *und man bediente sich nun derselben auch bey der Kirchenmusik.*' Footnote: '*Zuwelen ist er auch eine kleine Terz höher; jedoch nur in sehr alten Orgeln.*' Heinrich Christoph Koch, *Musikalisches Lexicon, welches die theoretische und praktische Tonkunst encyclopädisch bearbeitet, alle alten und neuen Kunstwörter erklärt, und die alten und neuen Instrumente beschrieben, enthält*', Frankfurt am Main 1802,327-8.

272 '*Ueber den Ton, in welchen das Instrument beym Stimmen gesetzt wird, bemerkte man, daß der Kammerton um einen ganzen Ton höher steht, als der Kapellenton, in Deutschland Chorton genannt, und das dieser letztere in den Kirchen üblich ist*' J. H. C. Nachersberg, *Stimmbuch, oder vielmehr: Anweisung, wie jeder Liebhaber sein Clavierinstrument, sey es übrigens ein Saiten- oder ein Pfeifenwerk, selbst repariren und also auch stimmen könne*, 2nd revised edition, Breslau and Leipzig 1804, 118. This passage also

Thon, in his handbook of 1817, provides interesting insights into the changes which apparently started taking place in the early nineteenth century. Thon is not as unequivocal as Koch but also describes choir pitch as more or less obsolete:

> 'As is known, it used to be that chamber pitch was a whole tone lower than the choir pitch and the latter a whole tone lower than the pitch of the old organs. This had to do with economy in making the largest pipes. Some time ago however one started raising the chamber pitch in many places by a semitone and now, for both vocal and instrumental music, there is only one pitch and the difference between chamber and choir pitch has disappeared by itself.
>
> 'This is not really the place to look into which pitch should be retained just on grounds of preference. One should be content if the instrument is designed and tuned according to a pitch which takes into account the place and circumstances. This pitch deserves to be indicated by the makers just as precisely as the string gauge markings so that it can be continually maintained. This is because the pitch is adjusted according to the scaling.'[273]

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occurs in *Clavier- Stimmbuch oder deutliche Anweizung wie jeder Musikfreund sein Clavier-Flügel, Forte-piano und Flügel-Fortepiano selbst stimmen, repariren, und bestmöglichst erhalen könne*, published by Gall, Vienna 1805, 66.

273 '*Ehemals stand, wie bekannt, dem Kammertone der Chorton entgegen und iener um einen ganzen Ton tiefer, als der Ton der ältern Orgeln, bei denen es um Ersparniß der größten Pfeife zu thun war. Seit geraumer Zeit hat man aber angefangen, den Kammerton an vielen Orten um einen halben Ton zu erhöhen und ietzt kennt man, sowohl für die Instrumental- als auch für die Vocalmusik nur eine Stimmung und der Unterschied zwischen Kammer- und Chorton fällt also von selbst weg.*

'*Es ist auch hier der Ort nicht, zu untersuchen, welchere Stimmton aus Gründen der Vorzug ausschließend behauptet und man kann schon zufrieden seyn, wenn das Instrument nach einem, auf Ort und Umständen berechneten, Hauptton eingerichtet und eingestimmt ist, welcher von dem Bauheern eben so pünktlich, wie das Nummerschema des Bezugs, angegeben zu werden verdient, um denselben stets beizubehalten,* Thon goes on to express the need for a standard pitch, a need which had still not been met by 1827. In a long discussion of pitch in the *Allgemeine musikalische Zeitung* of that year, published in Leipzig, the three pitches are again mentioned. Choir pitch is still described but again as a pitch of the past. The variation in chamber pitch, on the other hand, appears to have become exacerbated:

> 'From time immemorial here in Germany one has been used to distinguishing only two main pitches, the choir pitch and the chamber pitch.
>
> 'The first is separated by a whole tone from the latter, deeper pitch. But once there was also another, so-called cornet pitch, higher than both, which is only still found in very old organs, and then most rarely.
>
> 'The general opinion here is that in former centuries the choir pitch, namely the higher pitch, was most usually conventional and that the instruments were adjusted accordingly. Only after introducing different instruments at the courts for the private entertainment of the nobles in their chambers (and hence the name chamber pitch) was this lower pitch chosen. The reason for this was that the pitch used in the churches, the choir pitch, was considered too shrill. One became convinced that bowed and wind instruments sounded more beautiful and full at a somewhat lower pitch.
>
> 'In the end this chamber pitch became so widespread that even in the churches choir pitch gradually disappeared and today can only still be found in a few organs.'[274]

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da solcher nach der Mensur regulirt ist.' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 91.

274 *'Bey uns in Deutschland ist man von jeher gewohnt, nur zweyerley Hauptstimmungen zu unterscheiden: den Chorton und den Kammerton.*

'Der erstere soll von dem letzteren, tiefern, um einem ganzen Ton abstehen. Höher als beyde soll aber ehemals auch noch ein sogenannter

The writer continues with a description of the origins of pitches and a discussion of the pitches appropriate to playing 'old' music, that is, music of the seventeenth century. But the old pitches have not been handed down without change

> 'and what is worst, very arbitrary and, in different cities and countries, very unequal changes have been made such that by now Babylonian confusion is rife and there is scarcely anyone who can still say what is meant by chamber pitch. There are now as many pitches (claimed as chamber pitches) as cities of any importance in Europe and, what is more, even in one and the same city there is a plurality of recognised pitches.'[275]

The screwing upwards (*Hinaufschrauben*) of chamber pitch can be accurately documented, continues the text, thanks to Euler and

---

Cornettton existirt haben, der nur noch höchst selten auf sehr alten Orgeln gefunden wird.

'Die allgemeine Meinung bey uns ist, dass in früheren Jahrhunderten der Chorton, nämlich die höhere Stimmung, die am allgemeinsten übliche war; dass nach dieser auch die Instrumente eingerichtet gewesen; dass erst nach Einführung verschiedener Instrumente an den Höfen zum Privatvergnügen der Grossen, in den Kammern, jene tiefere Stimmung, welche von daher die Bennenung des Kammertons erhielt, aus dem Grunde gewählt worden sey, weil man die in den Kirchen eingeführte Stimmung, den Chorton, für die Kammer zu grell fand, und sich überzeugte, dass Bogen- und Blasinstrumente bey eine etwas tiefern Stimmung einen schönern und männlichern Ton erhielten.

'Dieser Kammerton wurde endlich so allgemein verbreitet, dass selbst in den Kichen der Chorton allmählig verschwand, und gegenwärtig nur noch auf wenig Orgeln mehr übrig seyn dürfte.' Allgemeine musikalische Zeitung, No. 9, 1827, 147. The author's name is not given.

275 '[...] *und was eigentlich das schlimmste dabey ist, sehr willkürliche, und in verschiedenen Städten und Ländern sehr ungleiche Veränderungen vorgenommen worden, so, dass jetzt schon eine babylonische Verwirrung herrscht, und schwerlich jemand mehr sagen kann, was unter Kammerton zu verstehen sey; dass es jetzt so vielerley Stimmungen (anmaassliche Kammertöne) giebt, als Städte von einiger Bedeutung in Europa, und dass sogar in einer und derselben Stadt mehre anerkannte Stimmungen zugleich bestehen. ' Allgemeine musikalische Zeitung*, No. 9, 1827, 148.

Chladni.

> 'According to Euler's calculation (in his *Tentamen novae Theoriae musicae etc.* Petersburg 1739) the eight foot or great C had 118 vibrations in one second [a'=397Hz].
>
> 'According to a later discussion in the written communications of the Petersburg Academy of the year 1771, *de motu aeris in tubis*, he found 125 [a'=420Hz], which agrees with Marpurg's observations (see the introduction to his discussion of temperament, 1776).
>
> 'Chladni calculated the vibration of great C at 128 [a'=431Hz.] in the year 1802 (at Wittenberg).
>
> 'In 1796 in Petersburg the *Kapellmeister* Sarti presented research to the Academy of Sciences according to which that the same C had already risen to 131 [a'=441Hz].
>
> 'Since then it has been driven even higher there, as Chladni has observed himself, if I rightly remember, to between 136 and 138 [a'=457-464Hz.].'[276]

After a small table setting out these pitches, the author states that the chamber pitch in St. Petersburg was already a whole tone above the contemporary chamber pitch in Berlin in the 1760's. He then continues, concentrating on Vienna.

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276 '*Nach Eulers Berechnung (in seinem* Tentamen novae Theoriae musicae etc. *Petersburg 1739) gab ihm damals das achtfüssige, oder grosse C in einer Secunde 118 Schwingungen.*

'*Nach einer spätern Abhandlung vom Jahre 1771,* de motu aris in tubis, *fand er 125; womit auch Marpurgs Beobachtungen (man sehe die Vorrede in seinem Versuche über die Temperatur, 1776) übereinstimmen.*

' *Chladni berechnete im Jahre 1802 (zu Wittenberg) die Schwingungen des grossen C auf 128.*

'*In Petersburg zeigte der Kapellmeister Sarti der Akademie der Wissenschaften im Jahr 1796 einige Versuche vor, nach welchen hervorgeht, dass daselbst jenes C schon bis auf 131 gestigen war.*

'*Seither soll es eben dort, wie ich von Hrn. Chladni selbst vernommen zu haben mich wohl entsinne, noch höher, auf 136 bis 138, getrieben worden seyn* [...].' *Allgemeine musikalische Zeitung*, No. 9, 1827, 148.

'I am not in a position to measure the usual pitches here in Vienna (for we have three pitches already in the theaters alone). There is however no doubt that our lowest tuning fork, the one of the *Hoftheater*, is about a semitone higher than, for instance, that in Leipzig from where I brought a flute with five *corps de rechange* in 1801 and had to give it away because it is useless here.

'Our tuning fork, I have certainly convinced myself, is higher than the Parisian one, which has already been driven upwards, and perhaps just the same as that in Petersburg.'[277]

The author then repeats Thon's plea for pitch standardisation.

G. W. Fink, in the article entitled *Chorton* in the '*Encyclopädie der gesammten musikalischen Wissenschaften, oder Universal-Lexicon der Tonkunst*' of 1835, edited by Gustav Schilling, draws largely on the *Allgemeine musikalische Zeitung* article for his entry on *Chorton*.

'The ordinary choir pitch or organ pitch was distinguished [in the past] from chamber pitch by a whole tone, so that the organ had to be played in C major if the instruments were performing in D major.'

But he goes on:

'Unfortunately however, there was so little consistency in the chamber pitch that there came into being an assortment

277 *'Ich bin nicht in der Verfassung, unsere hier in Wien jetzt üblichen Stimmungen (denn wir haben schon allein dreyerley Theaterstimmungen) zu messen; allein es ist kein Zweifel, dass unsere tiefste Stimmgabel, das ist die des Hoftheaters, etwa um einen halben Ton höher steht, als z.B. in Leipzig, von woher ich 1801 eine Flöte mit fünf Mittelstücken mitgebracht hatte, die ich hier als unbrauchbar habe weggeben müssen.*

'Unsere Stimmgabel ist, wie ich mich bestimmt überzeugte, höher als die schon hinaufgetriebene Pariser, und vielleicht vollkommen gleich jener zu Petersburg.' *Allgemeine musikalische Zeitung*, No. 9, 1827, 149.

of chamber tunings but no longer a chamber pitch...Just about every place of some importance had its own tuning. In Vienna there were even three different tunings in the various theatres. From all the reports it is clear that the chamber pitch was driven ever higher... The screwing upwards [*Hinaufschrauben*] of the pitches used in the orchestras has so increased that the choir pitch is now often much lower than the chamber pitch [...]'[278]

Summary

The third, virtually obsolete *Cornettton*, higher than both choir pitch and chamber pitch and mentioned by some of the above writers, does not concern us here. With regard to choir pitch and chamber pitch, the general consensus appears to be that after about 1800 choir pitch had also largely disappeared. Chamber pitch, on the other hand, flourished, varying even within a single city and generally showing a tendency to rise. The repeated description of an earlier, static condition in which the two pitch standards, choir and chamber pitch, coexisted at a whole tone apart, may of course not reflect the reality. Probably, in those

278 '*Der gewöhnliche Chor= oder Orgelton unterschied sich vom Cammertone um einen ganzen Ton, so daß die Orgel in C=Dur gespielt werden mußte, wenn die Instrumente D=Dur vortrugen...Leider aber blieb sich der Cammerton so weinig treu, daß es wohl eine Menge Cammertonstimmungen, aber keinen Cammerton mehr giebt* [...] *fast jeder etwas bedeutende Ort sene Stimmung für sich hatte, ja in Wien gab es sogar dreierlei Stimmungen auf den verschiedenen Theatern. Aus allen Angaben geht klar hervor, daß der Cammerton immer höher hinaufgetrieben wurde* [...]. *Das Hinaufschrauben der Tonhöhen in den Orchesterstimmungen hat so zugenommen, daß jetzt der Chorton oft viel tiefer ist, als der Cammerton* [...]' op. cit., II, Stuttgart, 1835, 234-5. Note '*Hinaufschrauben*', borrowed from the *Allgemeine musikalische Zeitung*, No. 9, 1827.

'former times' variation in pitch, even within a single city, was accepted as normal and the two nominal pitches, choir pitch and chamber pitch would have required no definition in absolute terms. The nineteenth-century ability to measure accurately and an emphasis on scientific enquiry brought variation to light and at the same time set the attempt to standardize in motion.

Pianos at choir pitch?

Alfons Huber has suggested that the piano makers will have designed instruments to sound at choir pitch as well as at chamber pitch.[279] Röllig did indeed state that his small portable *Orphica* was intended for choir pitch. But the *Orphica* cannot be considered as a mainstream instrument and there is little other evidence for pianos specifically for use at choir pitch. Nevertheless some builders, notably Hofmann and Streicher, appear to have made pianos with scalings designed for different pitches. These seem at first to substantiate Huber's thesis that choir pitch pianos were made but, as we shall see, it is more likely that these relatively long-scaled and thus presumably high-pitched pianos were simply intended for destinations where a particularly high chamber pitch

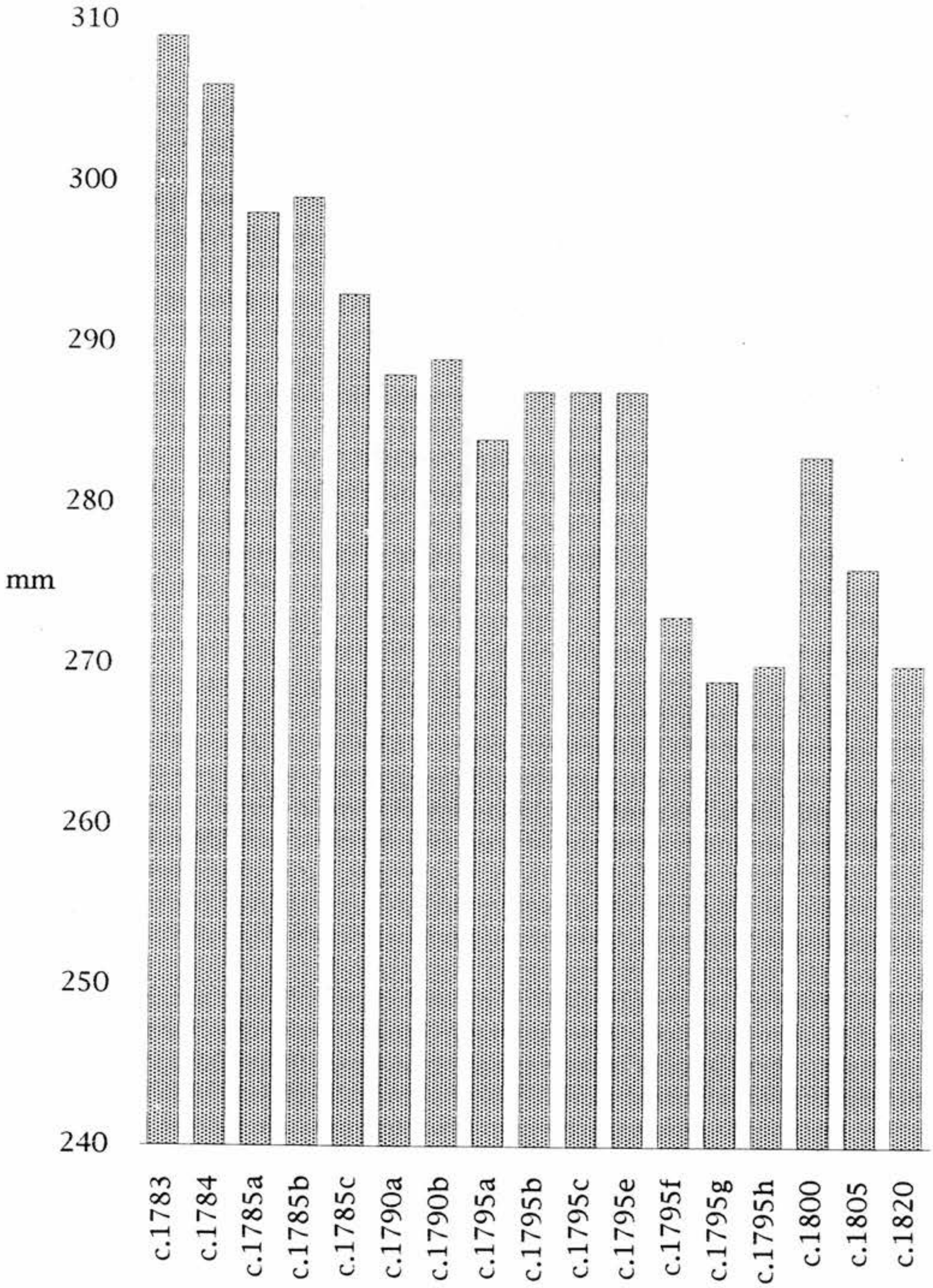
279 See Alfons Huber, 'Mensurierung, Besatung und Stimmtonhöhen bei Hammerklavieren des 18. Jahrhunderts (I & II)', *Das Musikinstrument,*, VII, July 1986. '*Hammerklaviere im Chorton erscheinen durchaus plausibel, wenn man einen Organisten als Besitzer annimmt. Die Stimmtonhöhe von a' = 455-460 Hz war in Osterreich bis ins 19. Jahrhundert gebräuchlich.*' A choir pitch of 455Hz and a chamber pitch of 430Hz are almost exactly a semitone apart (98 cents).

was in use. We now turn to these pianos.

Hofmann

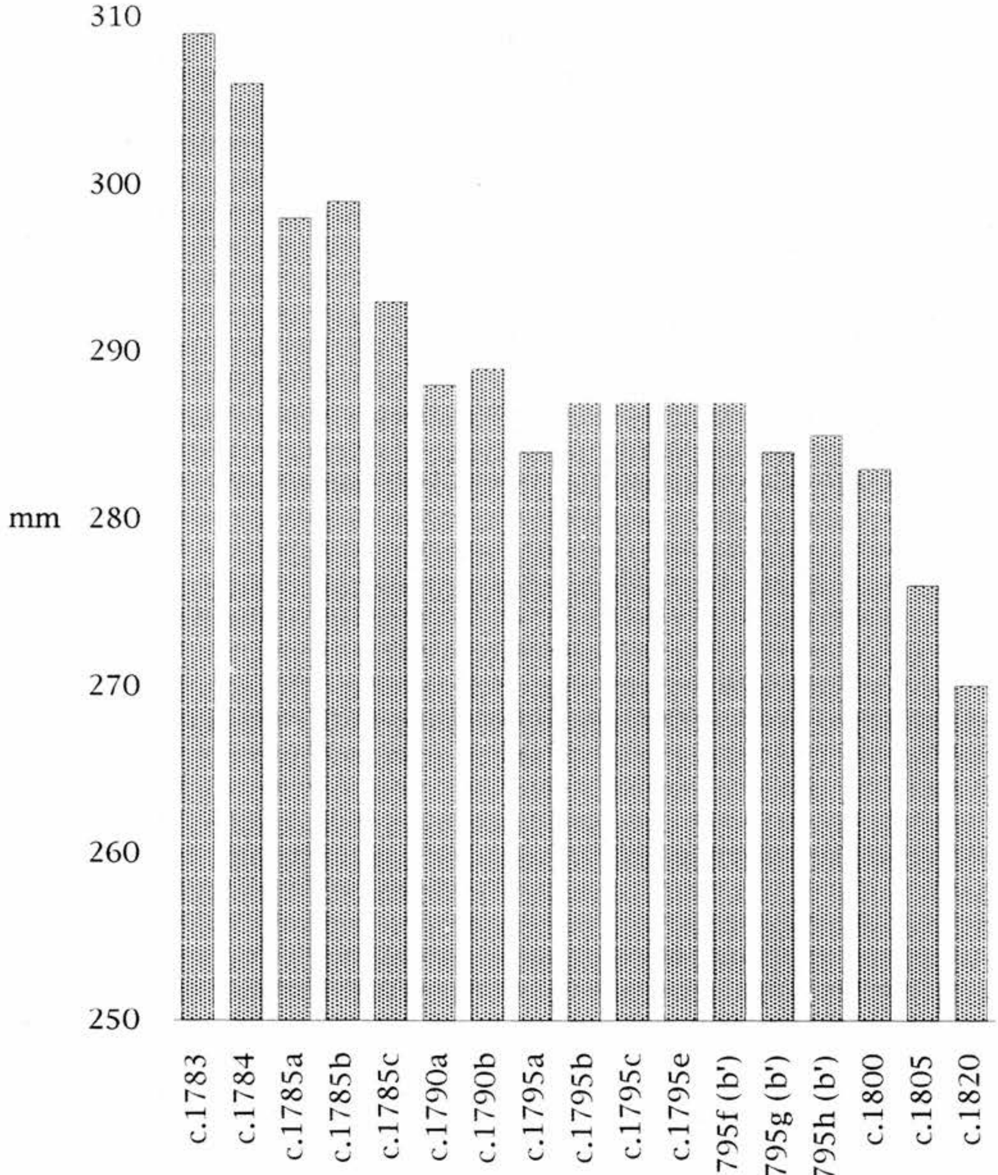
Hofmann's pianos are amongst those with string lengths which, for the upper half of the compass, appear to be designed using an octave ratio of 1 : 2 rather than with a tapered scale. In such cases the length of the c" string can be taken as representative of the treble scaling. Graph 97 charts the lengths of the c" strings of seventeen pianos by Hofmann in chronological order. Three of these, H/c.1795f, H/c.1795g and H/c.1795h, have treble scalings which do not conform to the pattern shown by the other thirteen; the string lengths of these three instruments are shorter, with c" string lengths of 273mm, 270mm and 269mm, averaging 271mm. The other pianos of the same period by Hofmann have an average c" string length of 286mm. The difference between the two averages is equivalent to exactly a semitone, suggesting that the three instruments were intended for a pitch a semitone higher than usual. When the lengths of the b' strings of these three instruments are compared (287mm, 285mm and 284mm) with the c" string lengths of the other thirteen, the three instruments fit the general pattern (graph 98).

Comparison of the c" string lengths
of 17 pianos by Ferdinand Hofmann



graph 97

Comparison of the scalings of 17 pianos by Hofmann
using the length of c" for normal pitch pianos and b' for those supposed to be intended for a higher pitch



graph 98

A comparison of the string lengths of H/c.1795f & H/1795c

	c.1795f	c.1795c			c.1795f	c.1795c	
		1636	FF	c'	548	550	c#'
FF	1621	1616	FF#	c#'	519	521	d'
FF#	1599	1597	GG	d'	490	492	d#
GG	1576	1574	GG#	d#	463	465	e'
GG#	1551	1551	AA	e'	437	439	f'
AA	1523	1527	AA#	f'	410	413	f#'
AA#	1492	1499	HH	f#'	386	388	g'
HH	1456	1467	C	g'	364	365	g#'
C	1417	1433	C#	g#'	344	343	a'
C#	1377	1397	D	a'	325	322	a#'
D	1337	1361	D#	a#'	305	304	h'
D#	1299	1325	E	h'	287	287	c''
E	1261	1289	F	c''	273	271	c#''
F	1224	1252	F#	c#''	258	257	d''
F#	1187	1215	G	d''	244	244	d#''
G	1151	1177	G#	d#''	231	230	e''
G#	1115	1140	A	e''	218	218	f''
A	1078	1102	A#	f''	207	207	f#''
A#	1043	1064	H	f#''	196	196	g''
H	1008	1026	c	g''	186	187	g#''
c	973	989	c#	g#''	176	178	a''
c#	938	951	d	a''	168	168	a#''
d	903	913	d#	a#''	159	160	h''
d#	869	879	e	h''	150	152	c'''
e	835	842	f	c'''	143	145	c#'''
f	800	806	f#	c#'''	135	137	d'''
f#	766	773	g	d'''	128	129	d#'''
g	734	738	g#	d#'''	121	121	e'''
g#	699	705	a	e'''	114	114	f'''
a	667	672	a#	f'''	107	108	f#'''
a#	636	641	h	f#'''	101	102	g'''
h	607	582	c'	g'''	94		

Table 78

Furthermore, if each string length of, for instance, H/c.1795f (probably intended for use at a high pitch) is compared with the string length of the note a semitone higher on H/c.1795c (a contemporary of H/c.1795f but probably intended for use at a standard pitch), the scalings of these two instruments are the same to within a few millemeters for most of the compass (table 78). The scaling designs of the two pianos are the same but shifted by a semitone in relation to each other.

Stein and his school

There is one piano by Stein with string lengths which also suggest a pitch about a semitone higher than his other instruments.[280] But the soundboard and wrestplank are new, so the bridge and nut may no longer be in their original positions.

One piano of the early 1790's by Franz Joseph Wirth, an apprentice of Stein who also settled in Augsburg, has a c" string length of 273mm whereas another, later piano by him dated 1803 has a c" string length of 289mm.[281] The difference between these two corresponds to a pitch ratio of almost exactly a semitone, with the earlier instrument at the higher pitch.

280 S/1785. The c" length of this instrument is 281mm while the c" length of S/1788a is 296mm. The ratio 296 : 281 is equivalent to 90 cents.

281 The one with a c" string length of 273mm is {England}, the other is {Munich}. The equivalent pitch difference between the two c" lengths is 99 cents.

Walter

Two of Walter's pianos have scalings which could imply a higher pitch. The c'' string length of W/c.1785c is 283mm while that of W/c.1785a is 297mm, representing a difference in pitch of 84 cents, just under a semitone. These two pianos are very similar in other respects. Their case lengths, for instance, are 2164mm and 2167mm. The six-octave instrument, W/c.1815g, has a c'' string length of 267mm while five other very similar Walter pianos of the same approximate date have c'' string lengths to within 3mm either side of 285mm.[282] The ratio 285 : 267 represents just over a semitone in pitch.

Choir pitch or high chamber pitch?

It thus emerges that while the traditional difference between choir pitch and chamber pitch, as described in the sources, is that of a whole tone, all the pianos with short scalings appear to have been designed by their makers to sound only a semitone higher than usual. This could be because chamber pitch had been raised to within a semitone of choir pitch. In both the '*Encyclopädie*' and the '*Allgemeine musikalische Zeitung*' chamber pitch is described as continually rising. Thon too seems to suggest that the difference

282 W/c.1815b, c, d, e and f all with the same range, FF to f'''' and approximately the same case length (2185mm varying 5mm either side).

had become only a semitone when he stated in 1817 that:

> 'Some time ago however one started raising the chamber pitch in many places by a semitone.'[283]

Röllig, however, when specifically discussing piano scalings in Vienna in 1795 (the approximate date at which the short-scaled pianos by Hofmann were built), is quite clear about a difference of a whole tone. The difference in the design exhibited by the pianos of Hofmann for an exact pitch difference of a semitone probably does not reflect actual differences between, for instance, the two different chamber pitches of two Viennese theatres or indeed a difference between choir pitch and chamber pitch. It is much more likely that Hofmann simply used a shortened version of the same basic scaling design when instruments were intended for destinations where a high chamber pitch was prevalent.

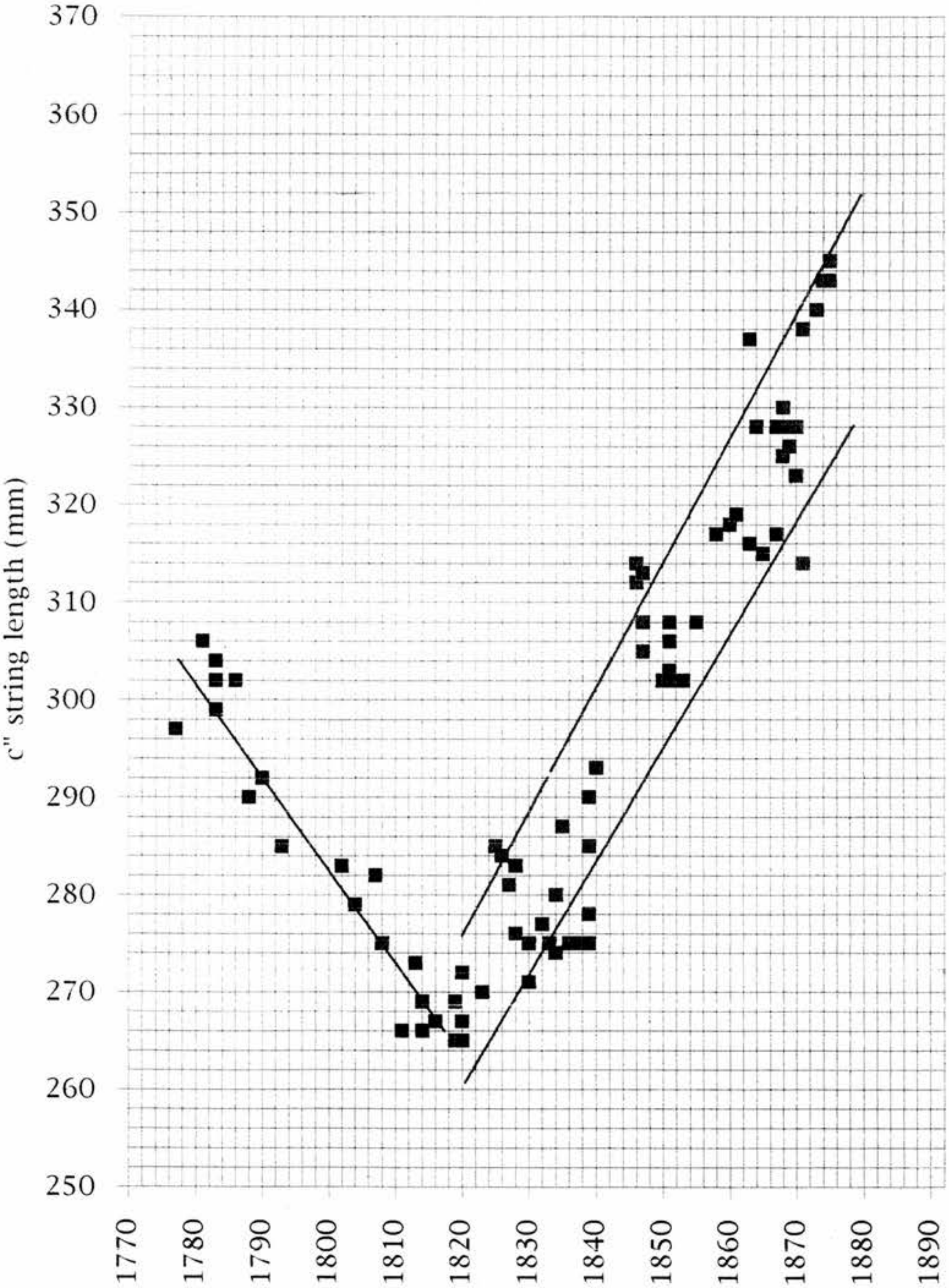
For one of his short-scaled pianos, H/c.1795f, Hofmann shortened all the string lengths by a semitone but left the case the normal length. In the other two, H/c.1795g and H/c.1795h, not only is each string length shorter, but the whole case is 14mm shorter in length (about half a Viennese inch or *Zoll*) than the average length of those of his other pianos.[284] The lengths of the FF strings of these two shorter pianos are 1613 and 1617, averaging

283 *'Seit geraumer Zeit hat man aber angefangen, den Kammerton an vielen Orten um einen halben Ton zu erhöhen.* ' Christian Friedrich Gottlieb Thon, *Ueber Klavierinstrumente, deren Ankauf, Behandlung und Stimmung. Ein nothwendiges Handbuch für ieden Besitzer dieser Art Metallsaiteninstrumente*, Sondershausen 1817, 91.

284 One Viennese *Zoll* equals 26.3186mm.

1615, the average length of the FF# strings of the normal length instruments and about half a *Zoll* shorter than the normal length of FF. The length of the case and the FF string length only varied within very narrow limits in Hofmann's pianos so that the differences in the case length and the FF string length between the three exceptional instruments on the one hand and the normal instruments on the other are significant. By simply shortening the whole design by a semitone, including the case and the strings, Hofmann could avoid making a completely new plan for those of his instruments destined for towns where the pitch was high.

Pianos of the Stein and Streicher firm
The variation in the length of the c" string with time



graph 99

The c" string lengths of a large number of instruments made by the Stein and Streicher firm are plotted in graph 99 against date of manufacture. The general tendency is that the scalings become shorter up to 1820. They then lengthen again, presumably indicating that from that date onwards the tensile strength of the wire used by the firm was continually being improved. After 1820 and until at least as late as 1870, the scalings vary considerably within periods of only a few years; the graph shows a broad band. The two near-parallel lines are spaced to represent two c" string lengths whose ratio corresponds to an interval of a semitone. At any one date the difference between the c" lengths indicated by the two lines is equivalent to a pitch difference of a semitone.

The differences in scaling shown on the graph are quite considerable. In 1839, for instance, the Streicher firm made pianos with strings differing in length by an amount equivalent to a semitone. Such differences could partly reflect the use of different strengths of wire.[285] But it is more likely that from about 1820 onwards the Streicher firm, like Hofmann earlier on, built instruments intended for different pitches, varying by as much as a semitone.

285 J. B. Streicher discusses the new English wire in his '*Über die Fabrikation englischen Hammertuches und englischer Gußstahlsaiten für Claviere*'. *Verhandlungen des niederösterreichischen Gewerb-Vereines*, viii, 1840, 64.

Alfons Huber has noted that the bells, part of the Janissary stop on a piano by Streicher of 1820 with a c" of 271mm, are tuned to a D-major triad at a' = 445Hz.[286] In the above graph a c" string length of 271mm, as found on this instrument, is about half way between the longest and the shortest theoretical string lengths used by the Streicher firm for c" in 1820. These extremes are obtained by extrapolating back from the longest and shortest c" string lengths used in the period after 1825. If the pitch a' = 445Hz is the average between the two extreme pitches represented by the longest and the shortest c" string lengths and if we know that these two extremes were a semitone apart we can say that the higher of these two pitches is a' = 459Hz and the lower a' = 430Hz.

Nannette Streicher is known to have exported pianos to Russia in 1816 and it is reasonable to assume that she continued to export instruments to Russia in the 1820's.[287] The pitch in St. Petersburg, according to the report in the '*Allgemeine musikalische*

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286 Alfons Huber, 'Saitendrahtsysteme im Wiener Klavierbau zwischen 1780 u. 1880', *Salzburger Museum Carolino Augusteum Jahresschrift*, 34/1988, note 35, 222. '*Da eine Streicherflügel von 1820 mit der gleichen kurzen Mensur* [c"= 271mm] *Glökchen aufweist,die einen D-Dur Dreiklang auf a' : 445Hz ergeben, kann man darauf schließen, daß die kürzere Mensur auf eine höhere Stimmtonhöhe zurükzuführen ist.*'

287 '*Er hat schon Briefe aus Russland, dass die Einfuhr der Wiener Instrumente dahin erlaubt sei mit 10 p.C. und ohne Bronze. Nur das Schloss und Firmaschild und das Fussende darf Bronze sein. Bei der Gelegenheit tadelte er die Bronzearbeit überhaupt, bei der so viel Gold, wie ganz verloren, verschwendet würde.*' Quoted from the diary of Dr. Karl Bursay of 24th June, 1816, by Otto Clemen in 'Andreas Streicher in Wien', *Neues Beethoven-Jahrbuch*, Vierter Jahrgang, Augsburg, 1930, 111.

Zeitung', had already risen to a'=457Hz at sometime before 1827 and even to a'=464Hz by 1827. Let us assume that the pitch there was a'=457Hz in 1820. This is in close agreement with the upper limit derived from the absolute pitch (a'=459Hz) of the Janissary bells on the piano of 1820 and the range of relative pitches given by the graph of the lengths of c" strings of Streicher pianos above.

The Streicher firm also sent instruments to Breitkopf & Härtel in Leipzig during the first two decades of the nineteenth century. The writer in the '*Allgemeine musikalische Zeitung*' states that the highest of the three theatre pitches in Vienna was about the same as the pitch in St. Petersburg but that the highest pitch in Leipzig was about a semitone below the lowest pitch in Vienna. The lowest pitch in Leipzig was thus more than a semitone lower than the upper limit of a'=459Hz.

We can conjecture that Streicher made pianos with strings long enough for a standard pitch of a'=430Hz. Those pianos destined for use at the highest pitch in Vienna or in St. Petersburg would have been scaled accordingly so that they could be tuned a semitone higher than the standard pitch, that is, they could be tuned to a'=459Hz, a semitone higher than a'=430Hz. Those pianos destined for a pitch lower than the standard pitch were apparently not given longer scalings, they must have simply been tuned down as required.

The facts and figures leading to these conclusions may be coincidental and are certainly tenuous. After all, the pitch of a set of bells on a single piano hardly provide firm ground for establishing a standard pitch for Streicher's pianos. Nonetheless, with a pitch in Leipzig lower than the lowest pitch in Vienna, at least three pitches in Vienna, the highest of which was about the same as an inordinately high pitch in St. Petersburg, it is not surprising to find instruments by the Streicher firm with varied scalings: pianos by the Streicher firm were used in all three of these cities.

Conclusion

In his *Kurze Bemerkungen über das Spielen, Stimmen und Erhalten der Fortepiano, welche von Nannette Streicher, geborne Stein in Wien verfertigt werden* published in Vienna in 1801, Andreas Streicher, the husband of Nannette, stated that a piano should be tuned to the wind instruments of the district. He then adds that

> 'Should the piano be tuned a half or a whole tone higher or lower, one tunes through the first time only roughly [...]'[288]

This remark, which implies that at the beginning of the nineteenth century the piano scalings must have been designed to accommodate pitches varying by about a whole tone, can reasonably be interpreted as implying a variation in pitch of a

288 '*Die Stimmgabel muss auf das richtigste mit den Blasinstrumenten, wie sie in dem Orte üblich sind, gleich stehen. Soll das Clavier einen halben oder ganzen Ton höher oder tiefer gestimmt werden, so stimme man es das erste Mahl nur überhaupt im groben durch* [...]. Andreas Streicher, *Kurze Bemerkungen über das Spielen, Stimmen und Erhalten der Fortepiano, welche von Nannette Streicher, geborne Stein in Wien verfertigt werden*, Vienna 1801, 30.

semitone higher or lower than a standard pitch. Hofmann appears to have solved the problem of this variation by building most instruments for the standard pitch, knowing of course that they could be tuned down a semitone if necessary, and by building a number of instruments exactly a semitone shorter for the highest pitch, thus avoiding any radical changes in his basic design.

Similarly, it appears that the Streicher firm built pianos for a standard pitch, that these pianos could also be tuned down to a lower pitch if required and that the firm also built instruments with especially short scalings adapted to pitches up to about a semitone higher than the standard pitch. These were for destinations like St. Petersburg or the theatre in Vienna where a high pitch prevailed.

An instrument with especially long strings can never be safely tuned up to a higher pitch while especially short strings can always be tuned down to a lower pitch. Tuning down, however, detracts from brilliance. To make all instruments capable of being tuned up to the highest pitch would probably have meant that instruments sent to destinations with a low pitch would have had their strings unacceptably under-stressed and thus lacking in lustre.

Hofmann, working at the end of the eighteenth century and Streicher, working in the 1820's, both appear to have been faced by the same problem. The pianos at standard pitch had scalings too long to be safely tuned up to the highest pitches used at home and abroad. For these high pitches both Hofmann and Streicher (and perhaps Wirth, Walter and others too) appear to have made especially short-scaled pianos. Pianos designed for standard pitch could be sent to destinations where the pitch used was low because the risk of breaking strings would only be reduced when the pianos were tuned down.

From the very little evidence offered by the very few remaining pianos the standard pitch for which the Viennese makers designed their instruments, at least for those made in the 1820's, appears to have been about a'=430Hz. This fragile deduction partially confirms one of the assumptions on which this essay is based.